Astronomy for All
Busan 2022

XXXIst General Assembly
International Astronomical Union

IAUGA 2022

August 2 (Tue) - 11 (Thu), 2022

BEXCO, Busan, Rep. of Korea

THE KOREAN ASTRONOMICAL SOCIETY

Korea Astronomy and Space Science Institute

ABSTRACT BOOK

Astronomy for All
Busan 2022

XXXIst General Assembly
International Astronomical Union

IAUGA 2022

CONTENTS

WELCOME MESSAGE

On behalf of the IAUGA 2022 National Organizing Committee, it is my greatest honor and privilege to invite you all to the XXXIst International Astronomical Union General Assembly (IAUGA 2022), to be hosted at BEXCO in Busan, Republic of Korea between August 2 and 11, 2022.

Initially, the NOC proposed “Astronomy for all” as the main theme, in a hope to make the Busan GA as inclusive as possible. As the COVID-19 pandemic hit the globe in early 2020, for the first time in the IAU history, the GA 2022 is being organized as a hybrid meeting, which allows both in-person and remote participation. New virtual elements such as remote talks, e-Talks, e-Posters, and an online chatting platform will be introduced to the GA logistics. After more than two years of online meetings, we believe astronomers are eager to meet our colleagues face-to-face. The NOC sincerely hopes that scientific programs will run smoothly for both in-person attendees and remote participants during the GA.

The host city, Busan, is the second largest city in the Republic of Korea, where contemporary lifestyle meets long-standing history with the state-of-the-art facilities and world-class infrastructure. All in-person attendees shall appreciate her rich natural, cultural, and urban legacies; and have a rewarding and productive time in every way in and around the GA.

Please join us for the festival of Astronomy in Busan.

Prof. Hyesung Kang
Chair
IAUGA 2022 National Organizing Committee

ORGANIZING COMMITTEE

IAU Executive Committee

President	Debra Meloy Elmegreen	
President-elect	Willy Benz	
General Secretary	José Miguel Rodriguez Espinosa	
Assistant General Secretary	Diana Mary Worrall	
Vice-President	Laura Ferrarese	Solomon Belay Tessema
	Hyesung Kang	Ilya G. Usoskin
	Daniela Lazzaro	Junichi Watanabe
Advisor	Ewine F. van Dishoeck	Maria Teresa V.T. Lago

IAUGA 2022 National Organizing Committee

Chair	Hyesung Kang	
Vice-Chair	Byeong-Gon Park	
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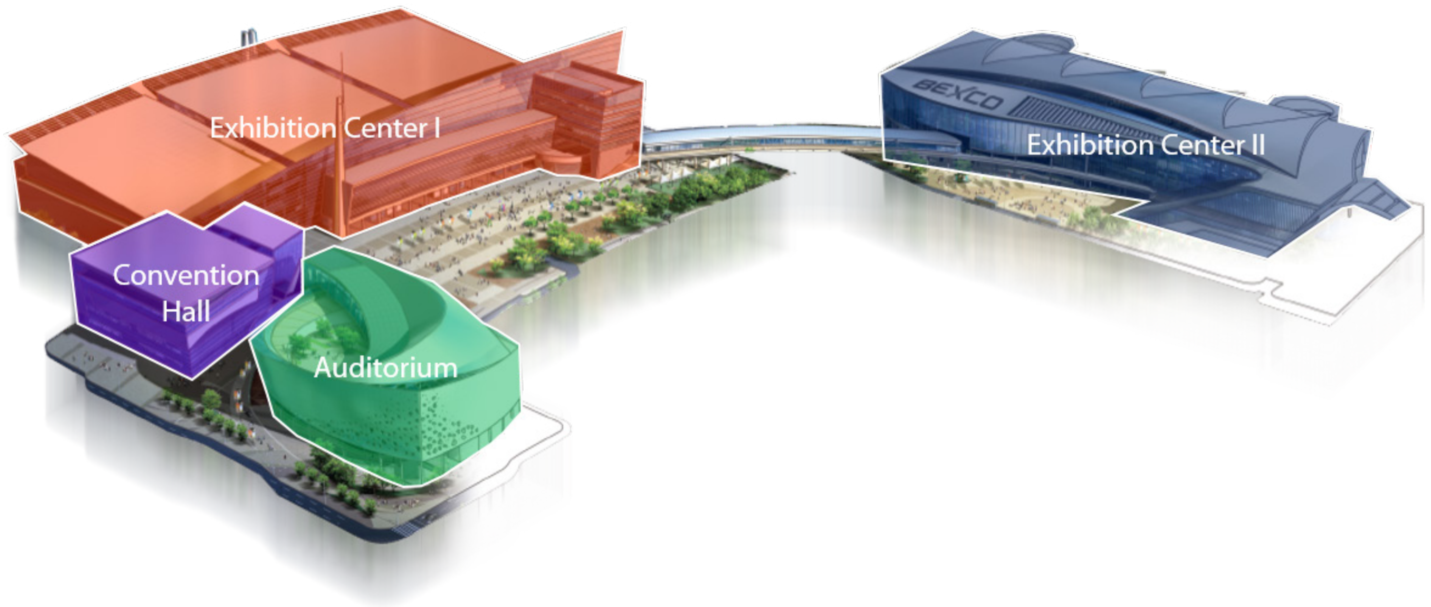
Ji-hoon Kim		In-Ok Song
Jongsoo Kim		Hong-Jin Yang
Minjin Kim		Suk-Jin Yoon
Sungsoo S. Kim		Sung-Chul Yoon

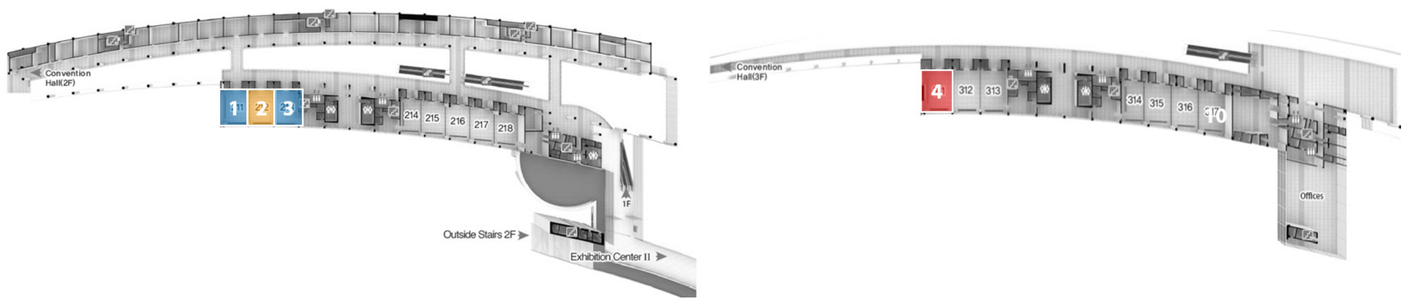
FLOOR PLAN



Auditorium

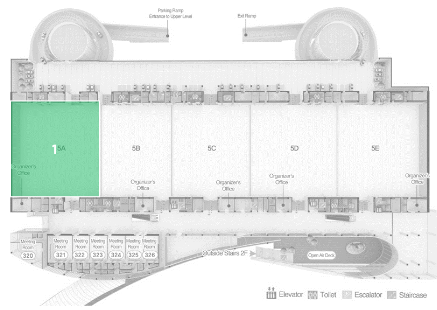
Floor	Room No.	Purpose	
2F	Auditorium	- Opening Ceremony - Symposium Plenary Lectures - Public Lectures	- Invited Discourses - Prize Lectures (Gruber, Kavli, Shaw) - Closing Ceremony

Exhibition Center I



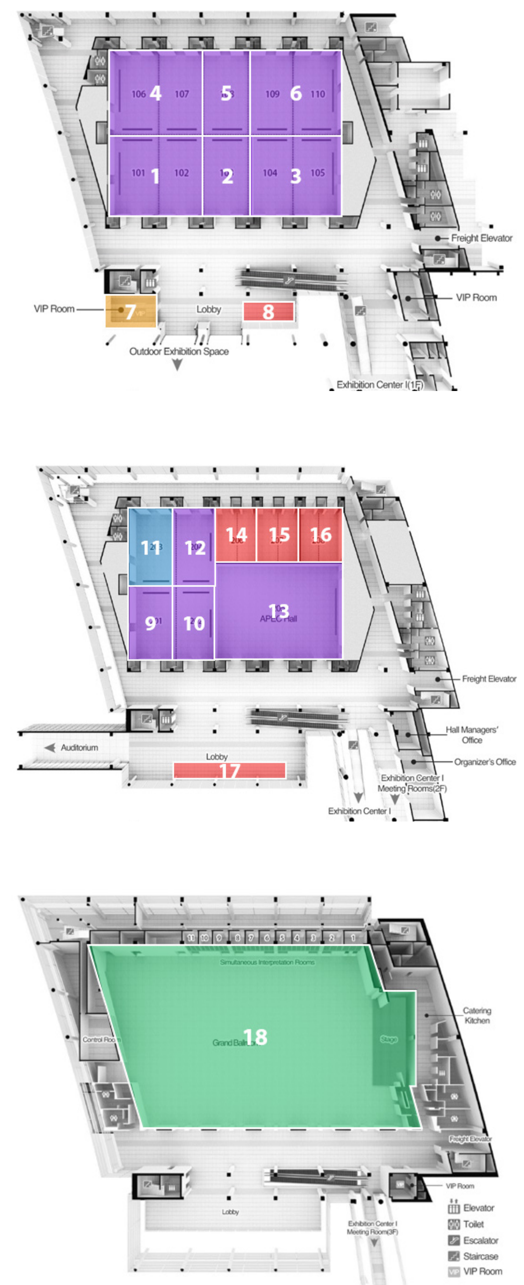
Floor	No.	Room No.	Purpose
2F	1	EC 211	E-Newspaper
	2	EC 212	Quiet Room / First Aid
	3	EC 213	Childcare
3F	4	EC 311	OAO, OYA, OAD, OAE

Exhibition Center II



Floor	Room No.	Purpose
3F	EC 2 Hall 5A	- YA Lunch - WiA Lunch - Conference Dinner

Convention Hall



Floor	No.	Room No.	Purpose
1F	1	CH 101	- Symposia - Division Meetings - Institutional Meetings
	2	CH 103	- Focus Meetings - Division Meetings - Institutional Meetings
	3	CH 104	- Symposia - Division Meetings - Institutional Meetings
	4	CH 106	- Focus Meetings - Division Meetings - Institutional Meetings
	5	CH 108	- Division Meetings - Institutional Meetings
	6	CH 109	- Focus Meetings - Division Meetings - Institutional Meetings
	7	VIP Room	NOC Office
	8	CH Lobby 1	Information Desk
2F	9	CH 201	- Small General Purpose Room (SGP) - Division Meetings
	10	CH 202	- Focus Meetings - Division Meetings - Institutional Meetings
	11	CH 203	Press Office
	12	CH 204	Preview Room
	13	CH 205	- Symposia - Division Meetings - Institutional Meetings
	14	CH 206	PCO Office
	15	CH 207	IAU Office
	16	CH 208	IAU Secretariat
	17	CH Lobby 2	Registration Desk
3F	18	Grand Ballroom	Exhibition / e-Posters

PROGRAM AT A GLANCE

	Week 1						Week 2			
	Tuesday August 2	Wednesday August 3	Thursday August 4	Friday August 5	Sat Aug. 6	Sun Aug. 7	Monday August 8	Tuesday August 9	Wednesday August 10	Thursday August 11
08:15-09:45		Morning Plenary S368	Morning Plenary S369	Morning Plenary S372			Morning Plenary S370	Morning Plenary S371	Morning Plenary S373	Morning Plenary S374
09:45-10:30	Morning e-Poster S368, S369, S372 FM4, FM5, FM8, FM9 Coffee Break	Morning e-Poster S368, S369, S372 FM4, FM5, FM8, FM9 Coffee Break	Morning e-Poster S368, S369, S372 OAO, OAD, OAE, OYA Coffee Break	Morning e-Poster Division Coffee Break			Morning e-Poster Division Coffee Break	Morning e-Poster S370, S371, S373, S374 FM1, FM2, FM10 Coffee Break	Morning e-Poster S370, S371, S373, S374 FM3, FM6, FM7 Coffee Break	Morning e-Poster S370, S371, S373, S374 FM3, FM6, FM7 Coffee Break
10:30-12:00	Morning Oral Session S368-1, S369-1, S372-1, OAO-1, FM4-1, FM5-1, FM8-1, FM9-1	Morning Oral Session S368-4, S369-4, S372-4, OAD-1, FM4-4, FM5-4, FM8-4, FM9-4	Morning Oral Session S368-7, S369-7, S372-7, OAE-1, FM1-1, FM2-1, FM10-1, OYA-1	Morning Oral Session Div. A-1, Div. B-1, Div. C-1, Div. D-1, Div. E-1, Div. F-1, Div. G-1, Div. H-1, Div. J-1			Morning Oral Session Div. A-4, Div. B-4, Div. C-4, Div. D-4, Div. E-4, Div. F-4, Div. G-4, Div. H-4, Div. J-4	Morning Oral Session S370-1, S371-1, S373-1, S374-1, FM1-4, FM2-4, FM10-4, WG1-3, WGAC	Morning Oral Session S370-4, S371-4, S373-4, S374-4, FM3-1, FM6-1, FM7-1, WG2-4	Morning Oral Session S370-7, S371-7, S373-7, S374-7, FM3-4, FM6-4, FM7-4, WG4-3
12:00-13:30	Lunch	Lunch Gruber Prize Lecture	Lunch Kavli Prize Lecture	Lunch Young Astornomers Lunch			Lunch Women in Astronomy Lunch	Lunch	Lunch Shaw Prize Lecture	Lunch
13:30-15:00	Afternoon Oral Session 1 S368-2, S369-2, S372-2, OAO-2, FM4-2, FM5-2, FM8-2, FM9-2	Afternoon Oral Session 1 S368-5, S369-5, S372-5, OAD-2, FM4-5, FM5-5, FM8-5, FM9-5	Afternoon Oral Session 1 S368-8, S369-8, S372-8, OAE-2, FM1-2, FM2-2, FM10-2, OYA-2	Afternoon Oral Session 1 Div. A-2, Div. B-2, Div. C-2, Div. D-2, Div. E-2, Div. F-2, Div. G-2, Div. H-2, Div. J-2			Afternoon Oral Session 1 Div. A-5, Div. B-5, Div. C-5, Div. D-5, Div. E-5, Div. F-5, Div. G-5, Div. H-5, Div. J-5	Afternoon Oral Session 1 S370-2, S371-2, S373-2, S374-2, FM1-5, FM2-5, FM10-5, WG1-4	Afternoon Oral Session 1 S370-5, S371-5, S373-5, S374-5, FM3-2, FM6-2, FM7-2, WG3-3	Afternoon Oral Session 1 S370-8, S371-8, S373-8, S374-8, FM3-5, FM6-5, FM7-5, WG4-4
15:00-15:15	Break						Break			
15:15-16:45	Afternoon Oral Session 2 S368-3, S369-3, S372-3, OAO-3, FM4-3, FM5-3, FM8-3, FM9-3	Afternoon Oral Session 2 S368-6, S369-6, S372-6, OAD-3, FM4-6, FM5-6, FM8-6, FM9-6	Afternoon Oral Session 2 S368-9, S369-9, S372-9, OAE-3, FM1-3, FM2-3, FM10-3, OYA-3	Afternoon Oral Session 2 Div. A-3, Div. B-3, Div. C-3, Div. D-3, Div. E-3, Div. F-3, Div. G-3, Div. H-3, Div. J-3			Afternoon Oral Session 2 OAO-4, OAD-4, OAE-4, OYA-4, WG1-1, WG2-1, WG3-1, WG4-1	Afternoon Oral Session 2 S370-3, S371-3, S373-3, S374-3, FM1-6, FM2-6, FM10-6, WG2-3	Afternoon Oral Session 2 S370-6, S371-6, S373-6, S374-6, FM3-3, FM6-3, FM7-3, WG3-4	Afternoon Oral Session 2 S370-9, S371-9, S373-9, S374-9, FM3-6, FM6-6, FM7-6, pro-am WG (WG 5)
16:45-17:30	Coffee Break (15 min.)	Afternoon e-Poster S368, S369, S372 FM4, FM5, FM8, FM9 Coffee Break	Afternoon e-Poster S368, S369, S372 FM1, FM2, FM10 ODE Prize Talks Coffee Break	Afternoon e-Poster Division Coffee Break			Afternoon e-Poster OAO, OAD, OAE, OYA WG1, WG2, WG3, WG4 Coffee Break	Afternoon e-Poster S370, S371, S373, S374 FM1, FM2, FM10 Coffee Break	Afternoon e-Poster S370, S371, S373, S374 FM3, FM6, FM7 Coffee Break	Coffee Break
17:30-18:30	Opening Ceremony Welcome Reception	Invited Discourse 1	Invited Discourse 2				Afternoon Oral Session 3 OAO-5, OAD-5, OAE-5, OYA-5, WG1-2, WG2-2, WG3-2, WG4-2	Conference Dinner	Invited Discourse 3	Closing Ceremony Flag Hand-over Ceremony
18:30-19:00										
19:00-19:30				Public Lecture 1	Public Lecture 2					
19:30-20:00										
20:00-20:30										

- S368 Machine Learning in Astronomy: Possibilities and Pitfalls
- S369 The Dawn of Cosmology & Multi-Messenger Studies with Fast Radio Bursts
- S370 Winds of Stars and Exoplanets
- S371 Honoring Charlotte Moore Sitterly: Astronomical Spectroscopy in the 21st Century
- S372 The Era of Multi-Messenger Solar Physics
- S373 Resolving the Rise and Fall of Star Formation in Galaxies
- S374 Astronomical Hazards for Life on Earth

- FM 1 Physics of Relativistic Jets on All Scales
- FM 2 Towards a World Standard for Dark and Quiet Sky Protection
- FM 3 Consensus Cosmic Shear in the 2020s
- FM 4 UV Insights to Massive Stars and Young Stellar Clusters
- FM 5 Beyond the Goldilocks Zone: the Effect of Stellar Magnetic Activity on Exoplanet Habitability
- FM 6 Dynamics of the ICM: Radio and X-ray Observations and Theory
- FM 7 Astrometry for 21st Century Astronomy
- FM 8 Planetary Astronomy via Telescopic and Microscopic Approaches
- FM 9 Stellar Synthetic Spectra to Study Stellar Populations in the Gaia Era
- FM 10 Synergy of Small Telescopes, and Large Surveys for Solar System & Exoplanetary Bodies Research

- WG1 Astronomy for Equity and Inclusion
- WG2 Global Coordination of Ground and Space Astrophysics
- WG3 Junior Members
- WG4 Women in Astronomy
- WG5 Professional-Amateur Relations in Astronomy

INVITED SPEAKERS

Early Science with the James Webb Space Telescope

Dr. Klaus Pontoppidan STScI

Invited Discourse 1
August 3, 2022 (Wed) 17:30-18:30

The Hubble Tension

Prof. Sherry Suyu MPA/TUM

Invited Discourse 2
August 4, 2022 (Thu) 17:30-18:30

Superflares and super Coronal Mass Ejections on Solar-type Stars

Dr. Hiroyuki Maehara NAOJ

Invited Discourse 3
August 10, 2022 (Wed) 17:30-18:30

Imaging a Supermassive Black hole

Prof. Sheperd S. Doeleman Harvard & Smithsonian

Public Lecture 1
August 5, 2022 (Fri) 19:00-20:30

The State of the Universe

Prof. Brian P. Schmidt Australian National University

Public Lecture 2
August 6, 2022 (Sat) 19:00-20:30

PRIZE LECTURES

Gruber Prize Lecture

A New Era of High Angular Resolution Astronomy

August 3, 2022 (Wed) 12:15-13:15

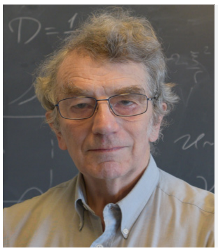
Dr. Frank Eisenhauer

Max Planck Institute for extraterrestrial Physics

Kavli Prize Lecture

The Historical Road and Future Path of Helio- and Asterosesimology

August 4, 2022 (Thu) 12:15-13:15

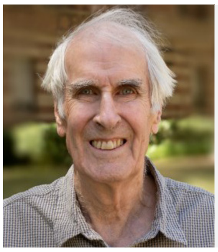


Prof. Jørgen Christensen-Dalsgaard

Aarhus University

Prof. Conny Aerts

KU Leuven & Radboud University



Prof. Roger Ulrich

UCLA

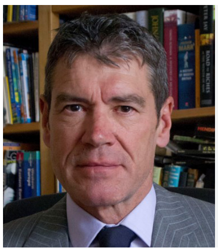
Shaw Prize Lecture

Gaia and Global Space Astrometry: A Historical Perspective

August 10, 2022 (Wed) 12:15-13:15

Prof. Lennart Lindegren

Lund University



Prof. Michael Perryman

European Space Agency

XXXI^st General Assembly
International Astronomical Union

IAUGA 2022

PROGRAM

WEEK 1:

August 2 (Tue) – August 5 (Fri), 2022

WEEK 2:

August 8 (Mon) – August 11 (Thu), 2022

Astronomy for All
Busan 2022

PROGRAM

WEEK 1

Day 1_August 2 (Tue)

Registration	2F Lobby, Convention Hall
Morning e- Poster	09:45-10:30, Grand Ball Room
Coffee Break	09:45-10:30, Grand Ball Room
Morning Oral Session	10:30-12:00, Convention Hall

Name	Abs. No.	Title
IAUS 368-1		**CH 205**
Sara Webb	3253	Tutorial for the broader community
IAUS 369-1		**CH 101**
Evan Keane	2678	Recent results from FRB surveys
Keith Bannister	1820	Fast Radio Bursts with ASKAP – in 3 acts
Kaustubh Rajwade	1552	Pinpointing FRBs in space and time: A study of localised FRBs from MeerTRAP
Franz Kirsten	1972	Pinpointing repeating FRBs with EVN-PRECISE
Joeri Van Leeuwen	2463	The short, high-DM FRB sky in sharp view
Omar Ould-Boukattine	2152	Probing the highest-energy FRB repeater bursts using thousands of hour observing campaigns
IAUS 372-1		**CH 104**
Robert Allen	2360	Parker Solar Probe in the Multi-Spacecraft Era
Bin Chen	2620	Recent Results of Solar Microwave Imaging Spectroscopy
Durgesh Tripathi	716	The Aditya-L1 Mission of the Indian Space Research Organization
OAO-1		**CH 108**
Jorge Rivero González	2973	IAU100: An Exciting Year Celebrating Astronomy
Eduardo Penteado	3434	IAU100 NameExoWorlds: naming stars and exoplanets through the public engagement

Somaya Saad	2328	Outreach activities in Egypt
Suresh Bhattarai	2698	Astronomy Outreach in Nepal: Creating a Legacy of Science Outreach

FM 4-1 **CH 202**

Andreas Sander	625	Massive Stars in the Far and Extreme Ultraviolet
Jorick Vink	849	X-Shooting ULLYSES
Kathryn Grasha	386	Non-solar scaled abundances for massive stars: the chemical abundance breakthrough for galaxy evolution
Olivier Verhamme	1501	Weakening the Winds with the ULLYSES Data Set: Examining the Presence of a Bi-Stability Jump

FM 5-1 **CH 103**

Bidya Binay Karak	297	Recent Developments in the Babcock-Leighton Dynamo Theory for the Solar Cycle
Vindya Vashishth	2902	Modelling the occurrence of grand minima in sun-like stars using a dynamo model
Rakesh Yadav	1713	Effect of planetary magnetic fields in the planetary habitability

FM 8-1 **CH 106**

Sei-ichiro Watanabe	757	Scientific discoveries of the Hayabusa2 mission, sample return from C-type asteroid Ryugu
Dante Lauretta	3073	OSIRIS-REx – Status of NASA's Near-Earth Asteroid Sample Return Mission
Beth Ellen Clark	2882	Overview of Space Weathering on Asteroid (101955) Bennu

FM 9-1 **CH 109**

Nathan Sandford	1325	Self-consistent stellar chemical abundance measurements: From near to far, high to low (resolution)
Yuan-Sen Ting	504	How many elements matter
Sven Buder	1408	Galactic Archaeology with spectra from the GALAH survey
Maria Luiza Linhares Dantas	2113	Old super-metal rich stars in the solar vicinity: from where did they come?

Lunch Break 12:00-13:30

Afternoon Oral Session 1 — 13:30-15:00, Convention Hall

Name	Abs. No.	Title
IAUS 368-2		**CH 205**
Guillermo Cabrera-Vives	3009	Classic Machine Learning vs Deep Learning: when, why and how?
Annalisa Pillepich	2178	ERGO-ML: Extracting Reality from Galaxy Observables with Machine Learning
IAUS 369-2		**CH 101**
Yin-Zhe Ma	1096	Cosmological uses of Fast Radio Bursts
Esan Mouli Ghosh	2696	Constraining the value of Hubble's Constant using the Redshift-Dispersion Measure distribution of observed Fast Radio Bursts
Khee Gan Lee	2558	The FLIMFLAM Survey for FRB Foreground Mapping
Sunil Simha	2235	Searching for the source of excess extragalactic DM of FRBs
Liam Connor	2500	What can we expect from FRB gravitational lensing?
Mawson Sammons	1094	The Effect of Gravitational Lensing on Fast Transient Event Rates
IAUS 372-2		**CH 104**
Sami Khan Solanki	709	The early science phase of Solar Orbiter
Thomas Rimmele	1250	The Daniel K. Inouye Solar Telescope: status update and first results
Hideyuki Hotta	944	Generation of the solar magnetic field
OAO-2		**CH 108**
Panel Discussion		IAU Astronomy Outreach under the IAU Strategic Plan 2020-2030
Panel Discussion		The role of the IAU members in the implementation of the Strategic Actions under Goal 4
FM 4-2		**CH 202**
Hugues Sana	2990	Massive Binaries and the UV Connection
Calum Hawcroft	2863	New Empirical Mass-Loss Rates and Wind Properties of Massive Stars at Low Metallicity
Gautham Narayana Sabhahit	1483	Mass-Loss Implementation and Temperature Evolution of Very Massive Stars

FM 5-2 **CH 103**

Stephen Marsden	1893	Stellar magnetic fields and the solar-stellar connection
Stefano Bellotti	601	Near-infrared Zeeman-Doppler Imaging of AD Leo with SPIRou: towards a magnetic polarity reversal?
Eliana Maritza Amazo-Gomez	422	What makes a stellar surface preferentially facular or spot dominated?
Lucia Kleint	2432	Solar Flares - an observational overview

FM 8-2 **CH 106**

Sunho Jin	914	Determination of space weathering timescale and consideration of a possible event occurred on Itokawa
Yoonsoo Bach	911	Thermal radiation pressure as a possible mechanism for losing small particles on asteroids
Youngmin JeongAhn	2596	Change of the Apophis' spin state during the 2029 Earth encounter
Oleksiy Golubov	2926	Tangential YORP torque due to the asteroid surface roughness
Jin Beniyama	2037	Subsecond Photometry of Tiny Near-Earth Objects with Tomo-e Gozen

FM 9-2 **CH 109**

Deokkeun An	1116	Empirical calibration of synthetic stellar spectra based on large photometric surveys
Rachael Beaton	2144	Stellar spectroscopy for cosmology: Prospects & challenges with late-type stars as standard candles
Dongwook Lim	1086	IGRINS high-resolution near-infrared spectroscopy of globular cluster candidates toward the Galactic bulge
Vinicius Branco	2895	A grid of synthetic spectra for the study of multiple populations in globular clusters

Break 15:00-15:15

Afternoon Oral Session 2 15:15-16:45, Convention Hall

Name	Abs. No.	Title

IAUS 368-3 **CH 205**

Michelle Lochner	1545	Machine Learning in Astronomy
Panel Discussion		Broader ML Topics

IAUS 369-3 — CH 101

Lachlan Marnoch	1945	Finding the signature of a dwarf galaxy halo on a fast radio burst
Timea Kovacs	2604	Constraining the dispersion measure and rotation measure contribution of FRB host galaxies using IllustrisTNG50
Kaitlyn Shin	1734	Inferring the FRB Distance and Energy Distributions with CHIME/FRB

IAUS 372-3 — CH 104

Allan Sacha BRUN	1196	Powering solar-type stars magnetism: how are magnetic cycles established and driven?
Ilya Usoskin	1201	Solar cyclic activity reconstruction now extends to cover the last millenniumZ
Hanna Strecker	1548	Tracking active regions from the near-Earth to the solar far side by combining SDO/HMI and SO/PHI data
Bhuwan Joshi	1515	Origin of extreme solar eruptive activity from the active region NOAA 12673 and the largest flare of solar cycle 24
Ting Li	339	Solar flare-CME association

OAO-3 — CH 108

Ana Ulla-Miguel	1969	OAO NOC Spanish activities
Dhanushka Amaradasa	2461	Case study: online hands-on astronomy activities for children during COVID-19
MANISHA DWA	2651	Astronomy outreach for inclusive environment in Nepal, it's impacts and challenges.
Maria Fernanda Durán	2518	Breaking the Barriers: Adding inclusive elements to astronomy outreach
Mayssa El Yazidi	1219	Inclusion and intercultural aspects of Astro-Tourism activities: Astro Camping Project in Djerba: The First step to develop Astronomy in Tunisia
Meriem Elyajouri	2455	Public Astronomy in Morocco: opportunities & challenges
Samir Dhurde	2225	Low-cost and Large-scale : a key to reaching most people
Tan Vu Nguyen	1449	A story about astronomy outreach in Vietnam: From an amateur club to a growing #scicomm ecosystem
Yumna Majeed	2771	Space Education and Outreach in Pakistan - Exploration by Yumna
Zara Randriamanakoto	1608	Building a network of amateur astronomers in Madagascar

FM 4-3 — CH 202

Miriam Garcia	923	Very Massive Stars and Very Metal-Poor Stars: Connected Topics?

Aida Wofford	1067	Are Very Massive Stars Truly Needed to Explain the Extreme Broad He II Emission of NGC 3125-A1?
Grace Telford	1804	The Ionizing Spectrum of an Extremely Metal-Poor O Star Powering an HII Region
Karla Arellano-Cordova	1340	Modeling the Ionizing Spectrum of Local Star-Forming Galaxies
Peter Senchyna	893	Direct Constraints on the Massive Stars Underlying Strong High-Ionization Nebular Emission Locally

FM 5-3 **CH 103**

Ying Liu	782	On the Formation of Solar Superstorms
Binal Patel	1539	Coronal mass ejections associated with DH type II radio bursts: near-Sun characteristics and interplanetary propagation
Julián Alvarado-Gómez	939	Coronal Mass Ejections and Exoplanets: A Numerical Perspective
Panel Discussion		

FM 8-3 **CH 106**

Patrick Michel	745	The impact process on small bodies: review of current knowledge and implications on the Solar System history
Gonzalo Tancredi	868	Dust trails generated on the DART experiment
Irina Belskaya	1514	The potential of optical polarimetry for asteroid studies
Jooyeon Geem	1126	Polarimetric Study on the Hydrates Asteroids

FM 9-3 **CH 109**

Mashhoor ALWARDAT	381	Al-Wardat's Method for analyzing binary and multiple stellar systems
Awni Kasawneh	1314	Stellar parameters of the close binary system: HIP 27758
Thayse Pacheco	1576	A grid of subdwarf's synthetic spectra to study hot stellar components in old stellar populations
Matheus Bernini Peron	1236	X-rays in stellar atmospheres: The case of cool B supergiants

Opening Ceremony 17:15-18:30, Auditorium

Welcome Reception 18:40-20:00, Auditorium Lobby

Day 2_August 3 (Wed)

Morning Plenary — 08:15-09:45, Auditorium

Name	Abs. No.	Title
IAUS 368		
George Djorgovski	1791	Machine Learning in Astronomy: From the Star-Galaxy Separation to a Collaborative Human-AI Discovery
Ofer Lahav	2189	Deep Learning in Astronomy: Trends and Challenges

Morning e- Poster — 09:45-10:30, Grand Ball Room

Coffee Break — 09:45-10:30, Grand Ball Room

Morning Oral Session — 10:30-12:00, Convention Hall

Name	Abs. No.	Title
IAUS 368-4		**CH 205**
Renee Hlozek	1870	Existing data sets for machine learning in Astronomy
Panel Discussion		Methodology for fusion of large datasets
IAUS 369-4		**CH 101**
Tarraneh Eftekhari	1860	The Host Galaxies and Environments of Fast Radio Bursts
Adaeze Lorreta Ibik	1704	A search for persistent radio sources associated with repeating fast radio bursts from CHIME/FRB
Calvin Leung	1170	VLBI Localization of a One-Off FRB to an Edge-On Galaxy
Marcin Glowacki	1134	A commensal detection of HI and FRB localisation with ASKAP
Shivani Bhandari	826	A growing diversity in the types of host galaxies and local environments for fast radio bursts.
Fabian Jankowski	1797	Implications from the first MeerTRAP Fast Radio Burst sample
IAUS 372-4		**CH 104**
Timothy Bastian	2283	Solar Observations with ALMA: a New Frontier
Maryam Saberi	956	MHD waves in chromospheric fibrillar structures as observed with ALMA
Devojyoti Kansabanik	389	Estimating physical parameters of quiet Sun corona using low-frequency spectro-polarimetric radio images

Yajie Chen	2444	Forward Modeling of Solar Coronal Magnetic-field Measurements Based on a Magnetic-field-induced Transition in Fe X

OAD-1 **CH 108**

Vanessa McBride	3041	Overview of OAD Activities
Peter Gluckman	3042	The changing shape of science diplomacy – the role of the International Science
Ian Corbett	3043	External review of the OAD
Ramasamy Venugopal	969	10 Years of Astro4dev Projects: Case Studies from Around the World
Dana Ficut-Vicas	423	Linking the outcomes of the IAU OAD Projects to the UN Sustainable Development Goals (SDGs)
María Alejandra Díaz Teodori	2839	The Impact of IAU OAD Projects on UN Sustainable Development Goals
Panel Discussion		History and Future of Astronomy for Development

FM 4-4 **CH 202**

Paul Crowther	416	Observations of Massive Stars in Extragalactic Star Clusters
Dooseok Jung	1024	Universal Upper Ends of the Stellar Initial Mass Function in the Young and Compact LEGUS clusters
Katarzyna Nowak	978	Could Kilomasers Pinpoint Supermassive Stars?
Mattia Sirressi	1433	Clues to Massive Star Clusters as Engines of Galaxy Evolution
Naira Azatyan	1749	The Stellar Content of UCHII Regions: The Molecular Cloud GRSMC 045.49+00.04

FM 5-4 **CH 103**

Antoaneta Antonova	1451	Recent studies of stellar flares across the electromagnetic spectrum
Timothy Bastian	2473	Radio Dynamic Spectroscopy of UV Cet and Prox Cen
Thomas Konings	950	The effects of stellar flares on the composition and spectra of gaseous exoplanets orbiting M dwarfs
Han He	1907	Characteristic time of stellar flares on Proxima Centauri
Eric Feigelson	1598	Pre-main Sequence Stellar Megaflares and Young Planetary Atmospheres

FM 8-4 **CH 106**

Takafumi Ootsubo	2565	Hydrated silicates on evolved cometary nuclei observed in the mid-infrared
Karri Muinonen	1944	Asteroid physical characteristics from Gaia photometry

Mingyeong Lee	1456	Laboratory study for the light scattering on planetary regolith with 3D printed models
Flora Paganelli	1313	Next Generation Ground-Based Planetary Radar Science at NRAO
Surhud More	1274	The search for Planet Nine using the Subaru Telescope
Amelia Yu	1370	Previously Undiscovered Exoplanets Detected with Deep Learning in the Data Collected by the Kepler Space Telescope
Hangbin Jo	913	Numerical study of low-velocity dust ejection from Phaethon and its connection to the Geminid meteoroid stream

FM 9-4 **CH 109**

Roel Lefever	1292	The challenges of modelling Wolf-Rayet atmospheres: Prescribed and dynamically-consistent winds
Luisa Fernanda Rodríguez Díaz	1794	Current status and future prospects of the STAGGER grid
Jonas Klevas	2873	3D hydrodynamical model atmospheres of M-dwarfs
Yixiao Zhou	2007	3D model atmospheres and line formation calculations with non-standard chemical compositions

Gruber Prize Lecture 12:15-13:15, Auditorium

Frank Eisenhauer — A New Era of High Angular Resolution Astronomy

Afternoon Oral Session 1 13:30-15:00, Convention Hall

IAUS 368-5 **CH 205**

Name	Abs. No.	Title
David Parkinson	555	Detecting complex sources in large surveys using an apparent complexity measure
Dennis Crake	2021	In Search of the Peculiar: An Unsupervised Approach to Anomaly Detection in the Transient Universe.
Didier Fraix-Burnet	1003	Unsupervised classification: a necessary step for Deep Learning?
Gordian Edenhofer	1049	Iterative Grid Refinement: Approximate Gaussian Processes for Billions of Parameters
Jeroen Audenaert	1830	Unraveling the physical mechanisms of pulsating stars through a multimodal and multidisciplinary machine learning approach
Lukasz Wyrzykowski	984	Time-domain photometry and machine learning with OGLE and Gaia

IAUS 369-5 — CH 101

Cherry Ng	1754	Observational constraints on FRB progenitors
Akshatha Gopinath	1967	Propagation effects in fast radio bursts as seen by the LOFAR telescope
Casey Law	1317	Finding FRB Sources without FRBs
Danica Scott	2577	The high-time resolution CRAFT FRB sample
Jakob Faber	1807	Compelling Morphologies of Fast Radio Bursts with CHIME/FRB Baseband Data
Ryan Mckinven	1717	Multi-year Polarimetric Monitoring of Repeating CHIME/FRB Sources (on behalf of the CHIME/FRB collaboration)

IAUS 372-5 — CH 104

Aline Vidotto	1191	How has the solar wind evolved to become what it is today?
Adam Finley	1465	Stirring the Base of the Solar Wind
Vishal Upendran	517	Exploring the formation solar wind, switchbacks and Quiet Sun heating
Marco Romoli	2795	First science with Solar Orbiter Metis coronagraph
Frédéric Auchère	2480	Solar Orbiter/EUI very wide field observations of the EUV corona

OAD-2 — CH 108

Olayinka Fagbemiro	327	Astronomy Education Outreach Efforts for Development in Africa
Onuche Ogu	2203	Impact of IDP Children Astronomy Outreach Project: A Data driven approach
Ahmed Estiak	2018	Investigating the effect of using the "Talking Planets" mobile application to increase students' engagement and knowledge of astronomy
Antonio J. Porras-Valverde	2222	Central American — Caribbean Bridge in Astrophysics
Mayssa El Yazidi	1271	Astronomical heritages and facilities in Tunisia
Nicolás Vásquez	695	Astrotourism around the middle of the world
SYED NAJAMUL HASAN	1708	Astronomy Education during the pandemic

FM 4-5 — CH 202

Sara Beck	633	STARS AND GAS IN CLUSTERS: FEEDBACK, EFFICIENCY AND EMERGENCE
Keunho Kim	1848	How Ionizing Radiation Escapes from Compact Star-Forming Regions in the Sunburst Galaxy
Lena Komarova	499	Lyman Continuum-Driven Superwind in Green Pea Analog Mrk 71

Name	Abs. No.	Title
Michael Rutkowski	2177	OVI Emission in the Halos of z~0.25 Star-Forming Galaxies
Varsha Ramachandran	374	Massive Star Feedback in the Magellanic Clouds and the Tidal Bridge

FM 5-5 **CH 103**

Name	Abs. No.	Title
Kosuke Namekata	1854	Hunting for stellar coronal mass ejections
Krisztián Vida	1575	Where are the stellar coronal mass ejections?
Heidi Korhonen	2346	Trying to catch the elusive stellar coronal mass ejections
Emilia Kilpua	2347	Space weather response to large-scale solar wind drivers

FM 8-5 **CH 106**

Name	Abs. No.	Title
Tomoko Arai	2576	DESTINY+ asteroid flyby of Geminid parent Phaethon
Yuri Aikawa	2155	Chemical link between protostellar cores, protoplanetary disks, and primordial objects in the Solar system
Maria Drozdovskaya	1459	Chemical Provenances of Cometary Volatiles

FM 9-5 **CH 109**

Name	Abs. No.	Title
Cis Lagae	496	Modelling the Milky Way's most metal-poor star
Gloria Canocchi	574	Improving planetary atmosphere characterization by 3D NLTE modeling of the stellar centre-to-limb effect
Xi Wang	349	Grids of 3D NLTE spectra in practice
Jack Mallinson	2400	Non-LTE impact of Ti I and Ti II on metal poor type star abundances

Break 15:00-15:15

Afternoon Oral Session 2 15:15-16:45, Convention Hall

IAUS 368-6 **CH 205**

Name	Abs. No.	Title
Panel Discussion		Practical Proble Solving - including interpretability

IAUS 369-6 **CH 101**

Name	Abs. No.	Title
Dongzi Li	839	A Highly Variable Magnetized Environment in a Pulsar Binary resembling Fast Radio Bursts
Dany Vohl	2395	Searching for FRB persistent radio source counterparts in dwarf galaxies using LOFAR

Danté Hewitt	2069	Monitoring repeating fast radio bursts with the Nançay Radio Telescope
Inés Pastor-Marazuela	1976	Deciphering the origin of FRBs with Apertif
Kenzie Nimmo	1446	A burst storm from FRB 20200120E in an M81 globular cluster
Ketan R Sand	1756	High Time resolution burst morphology of FRB 20180916B with CHIME/FRB
Mark Snelders	2164	Microsecond-duration bursts from FRB 20121102A

IAUS 372-6 **CH 104**

Christian Moestl	1282	The heliosphere in 3D from multi-spacecraft observations
Roksoon Kim	916	CME-CME interaction in the interplanetary space: Observation and simulation
Juan Carlos Martinez Oliveros	2246	2Pi steroradian radio observations of the 28-10-2021 solar flare
Jinhye Park	2381	A revisit to the source regions of solar energetic particles by the synchronic potential field source surface model
Tingyu Gou	980	Complete restructuring of a magnetic flux rope during a solar eruption

OAD-3 **CH 108**

Sonal Asgotraa	3044	Astrostays : Creating sustainable livelihoods through Community Led Astro-tourism
Armine Patatanyan	2656	Astronomy for Mental Health
Nikhita Madhanpall	2770	Data Science Exposure through Astro4dev Hackathons
Hyung Mok Lee	2397	Development of Modern Astronomy in the Korean Peninsula
Areg Mickaelian	1438	Astronomy in the Crossroads of Inter- and Multi- Disciplinary Sciences
Tawanda Chingozha	2628	Role of Science in Development – the case of Astronomy

FM 4-6 **CH 202**

Gustavo Bruzual	2523	Modeling Young Star Cluster Populations
Jaehong Park	2567	Calibrating Excursion Set Reionization Models to Approximately Conserve Ionizing Photons
John Chisholm	3013	What lurks below the Lyman Limit? Unearthing the unseen ionizing continua of extragalactic massive star populations
Kaelee Parker	3012	Tracing Massive Star Populations with Neutral and Low-Ionization Gas

FM 5-6 **CH 103**

Aline Vidotto	1190	Stellar space weather effects on potentially habitable planets

Judy Chebly	2593	Towards a better understanding of exoplanetary environments around cool stars
Robert Kavanagh	1154	Planet-enhanced activity from M dwarfs
Quentin Noraz	430	Evolution and diversity of the magnetism of the Sun and Sun-like stars
Panel Discussion		

FM 8-6 **CH 106**

Woojin Kwon	2157	A brief story of grain growth in young stellar objects
Shogo Tachibana	2213	Multi-Scale Understanding of C-type Near-Earth Asteroid (162173) Ryugu from Proximity Exploration by Hayabusa2 Spacecraft to Microanalysis of Returned Material
Maria Antonietta Barucci	493	Observing small bodies from light points to micro-particles

FM 9-6 **CH 109**

Hans-Günter Ludwig	2350	A library of high-resolution spectra of 3D model atmospheres
Anish Amarsi	1281	Accurate iron abundances of dwarf stars
Thomas Nordlander	790	3D abundance analysis of the most iron-poor stars
Tiago M. D. Pereira	2638	Speeding up 3D non-LTE spectral synthesis with neural networks
Piercarlo Bonifacio	993	Fiorella Castelli and her legacy

Afternoon e- Poster 16:45-17:30, Grand Ball Room

Coffee Break 16:45-17:30, Grand Ball Room

Invited Discourse 1 17:30-18:30, Auditorium

Klaus Pontoppidan Early Science with the James Webb Space Telescope

Day 3_August 4 (Thu)

Morning Plenary 08:15-09:45, Auditorium

Name	Abs. No.	Title
IAUS 369		
Victoria Kaspi	3076	Observational Properties of Fast Radio Bursts
J. Xavier Prochaska	3077	Mutli-wavelength studies and cosmological uses of FRBs

Morning e- Poster 09:45-10:30, Grand Ball Room

Coffee Break 09:45-10:30, Grand Ball Room

Morning Oral Session 10:30-12:00, Convention Hall

Name	Abs. No.	Title
IAUS 368-7		**CH 205**
Eric Ford	1546	Enhancing Exoplanet Surveys via Physics-informed Machine Learning
Panel Discussion		GW/MMA
IAUS 369-7		**CH 101**
Sergey Popov	284	FRB Emission mechanism theories vs. observations and population studies
Di Li	2333	Toward an Evolutionary Picture of FRBs
Marcus Lower	1489	Radio-loud magnetars as Galactic fast radio burst analogues
Navin Sridhar	1910	Radio nebulae from ULX Bubbles as Precursors of Common Envelope Events and Persistent Counterparts to Fast Radio Bursts
Mayuresh Surnis	2011	Slowly rotating neutron stars as potential counterparts to repeating FRBs
Zorawar Wadiasingh	2496	Ultra-long Period Magnetars
IAUS 372-7		**CH 104**
Elena Khomenko	2730	Understanding solar local dynamo
Jin-Yi Lee	2508	Plasma heating along a current sheet in nonequilibrium ionization and non-Maxwellian electron velocity distribution
Gwangson Choe	292	Why Are Solar Prominences Filamentary?
Sneha Pandit	2249	Formation of activity indicators in a 3D model atmosphere

Jongchul Chae	676	Detection of Propagating Alfvenic Waves in the Solar Chromosphere

OAE-1 **CH 108**

Robert Hollow	1859	Astronomy Education at CSIRO – What is the Role of a National Organisation?
Suresh Bhattarai	2703	Advocating for Astronomy Education in Nepal

FM 1-1 **CH 109**

Kazuhiro Hada	845	Event Horizon Telescope Observations of M87
Elisabete M. De Gouveia Dal Pino	1036	Magnetic Reconnection and Particle Acceleration in Relativistic Jets
Jae-Young Kim	1359	Space-VLBI view of the heart of M87 by RadioAstron at 22 GHz
Guang-Yao Zhao	1188	Unravelling the Innermost Jet Structure of OJ 287 with GMVA+ALMA Observations
Ilje Cho	1142	The Intrinsic Structure of Sagittarius A* at 1.3cm and 7mm

FM 2-1 **CH 103**

James Lowenthal	2300	Overview of Artificial Light at Night and Dark & Quiet Skies II recommendations
John Hearnshaw	1141	Light pollution: a unified global solution is needed for a global environmental problem
Discussion		
Sarah Brough	909	Impact of diffuse artificial light for different kinds of observations: optical wide field surveys
JAVIER DIAZ_CASTRO	683	The OTPC (Technical Office for the Protection of the quality of the Sky) of the IAC. Experience on Sky Law regulation
Zouhair Benkhaldoun	937	Site Protection in Morocco: Modelling the light pollution
Richard Wainscoat	1075	Protection of the dark night sky over Hawaii's observatories
Ramotholo Sefako	2159	SAAO Site Protection against Light and Dust Pollution
Abd El Fady Morcos	2029	Monitoring Light pollution at Kottamia Astronomical Observatory
Alemiye Mamo Yacob	1523	Astronomical site protection in Ethiopia
Discussion		
Antonia Varela	2740	Starlight Foundation: Night sky preservation and local socio-economic development
Hidehiko Agata	1200	The status of light pollution in Japan and its relation to astro-tourism

FM 10-1		CH 106
Hamed Valizadegan	616	ExoMiner: A Highly Effective Deep Learning Classifier to Mine Exoplanets
Andrew Vanderburg	738	Enhancing and Optimizing TESS's Scientific Output using Machine Learning
Rob Wittenmyer	1082	MINERVA-Australis: A Southern TESS follow-up machine
Sebastián Zúñiga-Fernández	2533	SPECULOOS: Hunting exoplanets of ultracool dwarfs with 1-meter ground-based telescopes network

OYA-1		CH 202
Itziar Aretxaga	761	The 5-decade long International Schoold for Young Astronomers program under observation
Monica Rubio	1361	My experience in the International School for Young Astronomer
Xiaohui Fan	2296	ISYA 1992 and my career in astronomy
Somaya Saad	2321	The learned lessons from ISYA
Kingsley Okpala	2921	Reflection on the 1999 International School for Young Astronomers and its Impact on Personal and Professional life.
Discussion		

Lunch Break		12:00-13:30
Kavli Prize Lecture		12:15-13:15, Auditorium
Jørgen Christensen-Dalsgaard		The historical road and future path of helio- and asteroseismology
Conny Aerts		
Roger Ulrich		

Afternoon Oral Session 1		13:30-15:00, Convention Hall
Name	Abs. No.	Title

IAUS 368-8		CH 205
O. Ivy Wong	927	A review of current tools for outreach & education
Melissa Lopez	1744	Simulating Transient Noise Bursts in LIGO with Generative Adversarial Networks
Mike Walmsley	1150	Galaxy Zoo: Practical Methods for Large-Scale Learning
Joshua Speagle	707	Incorporating Errors in Machine Learning Methods

IAUS 369-8 — CH 101

Shriharsh Tendulkar	3059	Multi-messenger and Multi-wavelength observations of FRBs
George Younes	2467	Dissecting the radio/X-ray connection in the FRB-emitting magnetar SGR 1935+2154 and implications for the rest of the population
Kelly Gourdji	2398	Testing a neutron star merger origin for some FRBs
James Chibueze	280	A MeerKAT, e-MERLIN, H.E.S.S. and Swift search for persistent and transient emission associated with three localised FRBs
Suryarao Bethapudi	2431	FRB 20180916B observing campaigns using uGMRT and Effelsberg
Yuu Niino	2589	High time-resolution optical limits on bursts from repeating FRB 20190520B by simultaneous 24.4 fps observations with Tomo-e Gozen

IAUS 372-8 — CH 104

Yong-Jae Moon	1961	Application of Deep Learning to Solar and Space Weather Data
Neal Hurlburt	833	Heliophysics Events Knowledgebase support for Multi-Messenger Solar Physics
Henrik Eklund	2078	Deep neural network estimator for image refinement and estimation on radiation formation heights
Andrea Diercke	500	Automatic Extraction of Solar Filaments Using Machine Learning Techniques
Bendict Lawrance	597	Generation of coronal white light images from SDO/AIA EUV images using deep learning

OAE-2 — CH 108

Aniket Sule	2433	Nurturing Excellence in Astronomy at School Level
Mayssa El Yazidi	1227	An Astronomical Observatory in Djebel Orbata (Gafsa): A proposal for an academic project in Tunisia

FM 1-2 — CH 109

Jongho Park	1739	Collimation and Acceleration of AGN jets
Giancarlo Mattia	2047	Jets from accretion disk dynamos: a consistent model for dynamo and resistivity
Andrew Chael	1904	Supermassive black holes and relativistic jets: insights from simulations and Event Horizon Telescope observations
José L. Gómez	3409	The filamentary structure of 3C279 probed by RadioAstron
Stefan Wagner	1817	Constraints on Particle Acceleration in Relativistic Jets from Gamma-ray observations

FM 2-2		**CH 103**
Ruskin Hartley	2490	IDA's international program for dark sky preserves as a model
Discussion		
Hector Linares Arroyo	2196	Modeling to Mitigate the Impact of ALAN
Salvador J. Ribas	602	Measurement for Regional Monitoring
Ana Ulla-Miguel	1558	The Gaia4Sustainability project: assessing light pollution aided by natural night sky brightness modelling
Discussion		
Yana Yakushina	1401	Legal protection of dark skies above major observatories
Christian Adam	2452	Applying astronomical techniques to characterize ground-based light polllution sources
Pedro Sanhueza	2356	The Chilean Norma Luminica and the research group on ALAN

FM 10-2		**CH 106**
Jessie Christiansen	2825	Exoplanet Demographics: Exploring the Multiplicity of Planetary Systems
Ernst De Mooij	827	Characterising the atmospheres of exoplanets using high-resolution transmission spectroscopy
William Welsh	1386	Using Small Telescopes to Photometrically Determine the Masses of Tatooine Planets
Zouhair Benkhaldoun	1811	Small telescopes and big projects

OYA-2		**CH 202**
Chris Woolston	1009	The Challenges and Possibilities of a Science Career: Lessons from Nature
Luis Salazar-Manzano	1226	Challenges faced by Latin American astronomy students
Etsegenet Getachew	1592	Challenges for African's Women in Science
Daudi Mazengo	1211	Challenges facing PhD students in astronomy: A practical experience.
Hira Fatima	1263	Challenges of PhD students nowadays
Open Discussion		

Break 15:00-15:15

Afternoon Oral Session 2 — 15:15-16:45, Convention Hall

Name	Abs. No.	Title
IAUS 368-9		**CH 205**
Raquel Ruiz Valença	2501	Comparing machine learning and deep learning models to estimate quasar photometric redshifts
Steffani Grondin	1203	Searching for the extra-tidal stars of Galactic globular clusters with high-dimensional clustering analysis
Vishal Upendran	515	Accelerating astronomy workflow with deep learning and interpretable A.I
Yuan-Sen Ting	503	Quantifying non-Gaussianity with mathematical insights from machine learning
IAUS 369-9		**CH 101**
Alice Curtin	1560	Searching for FRB-like Counterparts from GRBs using the First CHIME/FRB Catalog
Mike Walmsley	2419	Candidate Faint Fast Radio Bursts Found by Citizen Scientists
Pragya Chawla	1785	A search for low-frequency FRB emission with the LOTAAS survey
Stella Ocker	691	Scattering Horizons for Fast Radio Bursts
IAUS 372-9		**CH 104**
Clementina Sasso	1194	Modeling efforts for multi-mission science
Andrew Walsh	1725	Coordinating Solar Orbiter Operations: The Story so far and What to Expect Next
Alexandra Tritschler	2647	DKIST Coordination: Status and Current Strategies
Yang Su	1927	Progresses of ASO-S mission
OAE-3		**CH 108**
Rosa Doran	2789	Digital Education and Inclusion Leading the New Trends in Education
Asmita Redij	1436	A spreadsheet-based tool to analyse astronomy content in textbooks
FM 1-3		**CH 109**
Philip Edwards	1936	The parsec-scale properties of TeV blazars
Markus Boettcher	1694	A shock-in-jet synchrotron mirror model
Z. Lucas Uhm	2680	Physics of Relativistic Jets in Gamma-ray Bursts in the Era of Multi-messenger Astronomy

James Leung	1886	Unveiling gamma-ray burst jet properties with radio observations
Florian Eppel	2679	First Results of the TELAMON AGN Monitoring Program In the Light of the Doppler Crisis and Neutrino Emission
Gaëtan Fichet de Clairfontaine	667	Characteristic multi-wavelength emission signatures from strong shock-shock interactions in perturbed relativistic jets

FM 2-3 **CH 103**

Discussion		
Federico Di Vruno	2319	Radio astronomy and the quest for Quiet Skies
Gyula I. G. Józsa	2364	How radio frequency interference affects astronomy
L. Viktor Tóth	2878	Endangered frequency bands
Divya Oberoi	1352	Managing Radio Frequency Interference at the Giant Metrewave Radio Telescope
Karen Masters	1653	Update on Activities of The US National Academies' Committee on Radio Frequencies (CORF)
Carol Wilson	1991	Characteristics of Radio Quiet Zones
Haiyan Zhang	700	Recent Progress on Proposed National Standard of Electromagnetic Environmental Protection for Radio Telescopes
Bevin Vanderley	2889	Radio Astronomy Dynamic Coordination Zones
Discussion		

FM 10-3 **CH 106**

Siegfried Eggl	2223	Solar System Science opportunities with the Vera C. Rubin Observatory Legacy Survey of Space and Time
Federica Spoto	1322	The Gaia Follow Up Network: state of the art and future objectives
Stephen Gwyn	474	Recycling photons: The uses of archives in solar system searches
Anatoliy Ivantsov	2704	Astrometric bias due to overlapping image profiles in the focal plane and its removal in the positions of near-Earth asteroids

OYA-3 **CH 202**

Round Table		
Michele Gerbaldi		The School model for the Office for Young Astronomers: Challenges perceived from within the IAU

Afternoon e- Poster	16:45-17:30, Grand Ball Room
Coffee Break	16:45-17:30, Grand Ball Room

ODE Prize Talks	17:00-17:30, CH 205

Invited Discourse 2		17:30-18:30, Auditorium
Sherry Suyu	The Hubble Tension	

Day 4_August 5 (Fri)

Morning Plenary — 08:15-09:45, Auditorium

Name	Abs. No.	Title
IAUS 372		
Valentin Martinez Pillet	2818	Challenges and opportunities in solar and heliospheric physics at the dawn of the multi-messenger era

Morning e- Poster — 09:45-10:30, Grand Ball Room

Coffee Break — 09:45-10:30, Grand Ball Room

Morning Oral Session — 10:30-12:00, Convention Hall

Name	Abs. No.	Title
Div. A-1		**CH 103**
Div. B-1		**CH 101**
Francisco Javier Bailen	3466	Spectropolarimetric and imaging properties of Fabry-Pérot etalons. Applications to solar instruments.
Danna Qasim	260	Laboratory studies of interstellar methane ice in the era of JWST
Luke Pratley	1256	Exact wide-field interferometric imaging via distributed sparse image reconstruction
Niels Ligterink	1145	The astrochemical factory: producing the first biomolecule building blocks
Div. C-1		**CH 104**
Tim Spuck	2820	Making Image Analysis Accessible to the Blind: IDATA and the Afterglow Access Software
Anna Voelker	2778	SciAccess, Inc.: Best Practices for Accessible Astronomy Outreach
Linda Strubbe	1803	Centering compassion and interaction in online teaching
Tsolmon Renchin	1663	Astronomy for Mental Health and Wellbeing
Jarita Holbrook	281	ASTROMOVES: Career Fluctuations due to the COVID-19 Global Pandemic

Div. D-1 — CH 201

Ziggy Pleunis	1078	Fast radio burst detection and differentiation with the CHIME telescope
Manuel Linares	599	Compact binary millisecond pulsars and the neutron star mass distribution
Wynn Ho	692	Masses and beyond with neutron star cooling
Cole Miller	520	X-ray measurements of neutron star masses and radii

Div. E-1 — CH 108

Dibyendu Nandi	1788	Predicting the Solar Cycle: Where Do We Stand?
Maria Madjarska-Theissen	740	The Solar Atmosphere at Small Scales: Loops and Associated Dynamic Phenomena
Kilian Krikova	2739	Diagnostic Potential of Hε for Small-Scale Energetic Phenomena
Arkadius Berlicki	2479	Quiescent Prominence Diagnostics Based on ALMA, UV and H-alpha/ MSDP Observations
Stanislav Gunar	725	Solar Lyman-Alpha and Mg II h&k Radiation Variability with the Solar Cycle and its Impact on the Diagnostics of Chromospheric and Coronal Structures

Div. F-1 — CH 202

Athena Coustenis	473	Exploration of habitable worlds in the outer solar system: the icy moons
Przemek Mroz	974	Exploring the free-floating planet population with gravitational microlensing
Jane Huang	383	Rings and Spirals in Protoplanetary Disks: The ALMA View of Planet Formation

Div. G-1 — CH 106

Roel Lefever	994	Towards a more realistic description of Wolf-Rayet atmospheres
Suman Bala	2110	A new Monte-Carlo radiative transfer simulation of cyclotron resonant scattering features
Oleksandr Yushchenko	2856	Radioactive elements with long and short decay times in stellar atmospheres
Innocenza Busa	2797	Magnetic pressure a necessary contribution to pressure in stellar atmosphere modeling

Div. H-1 **CH 109**

Meriem Elyajouri	2888	Studying the ISM in the Era of JWST
Sal Fu	2241	Metallicity Distribution Functions of Local Group Dwarf Galaxies from Hubble Space Telescope Narrow-band Imaging
Ekta Patel	608	Constraining the Total Mass of M31 with Precision Astrometry
Katie Chamberlain	475	Implications of the travel velocity of the Milky Way on Local Group mass estimates from the Timing Argument
Ayami Hotta	1604	Formation of the Andromeda Giant Southern Stream and the 10 kpc ring in the Andromeda galaxy

Div. J-1 **CH 205**

Kim-Vy Tran	1296	Welcome to Division J Meeting
Anna-Christina Eilers	2716	The Growth of Supermassive Black Holes in the Early Universe
Sree Oh	797	Kinematic scaling relations for galaxy bulges, disks, and ionized gas from 3D spectroscopy
Seok-Jun Chang	816	Lyα Radiative Transfer in Continuous and Clumpy Spherical H I Halo with a Central source
Médéric Boquien	1544	Dust emission templates for star-forming galaxies in the era of JWST

Lunch Break 12:00-13:30

Young Astronomers Lunch 12:00-13:30, Hall 5A, Exhibition Center II

Afternoon Oral Session 1 13:30-15:00, Convention Hall

Name	Abs. No.	Title

Div. A-2 **CH 103**

Div. B-2 **CH 101**

Habib Khosroshahi	806	The Iranian National Observatory 3.4 m optical telescope
Di Li	710	The Commensal Radio Astronomy FAST Survey (CRAFTS) and its discovery potential
Giorgio Matt	355	Imaging X-ray Polarimeter Explore (IXPE) first results
Rohini Joshi	1044	SKAO and SRC Data Reduction

Div. C-2 **CH 104**

Gianna Cauzzi	2557	COMMUNITY EDUCATION TO FOSTER FACILITY ENGAGEMENT: THE EXAMPLE OF THE DKIST DATA TRAINING WORKSHOPS
Heidi Korhonen	2358	Young astronomer hands-on training with virtual schools
Tomasz Mrozek	2090	Astronomy lectures in the far away country
Surhud More	1291	IUCAA Scipop: Astronomy outreach in India during the COVID era
Nishan Lamichhane	317	Engaging and motivating students using astronomical tools during the COVID-19 pandemic
Michael Fitzgerald	3072	Benefits and Detriments in the move to online learning with remote telescopes

Div. D-2 **CH 201**

Laura Becerra Bayona	256	SPH simulations of the Induced Gravitational Collapse mass spectrum of gravitational-wave mergers
Gayathri Vivekananthaswamy	3021	GWTC3: compact objects with different sizes and shapes
Ayan Bhattacharjee	1971	Could a Unified Spectral Model Estimate the Mass of Accreting Compact Objects?
Michela Mapelli	371	Oversize black holes: Formation channels of the most massive black holes observed by LIGO and Virgo
Gaston Escobar	2065	Demography of binary black holes with the population-synthesis code SEVN

Div. E-2 **CH 108**

Tetsuya Magara	2420	Modeling of Solar Magnetic Phenomena: Past, Present, and Future
Peng-Fei Chen	2722	Observational Features of Solar Filaments and their Implications
Tomasz Mrozek	1985	Plasma Characteristics During Microflares from Combined STIX-STEREO Observations and Hydrodynamical Modeling
Vemareddy Panditi	1385	On the Evolution of Magnetic Helicity Flux from Solar Active Regions: Our Present Understanding
Bhuwan Joshi	1547	Evolution of Magnetic Fields and Energy Release Processes during Homologous Eruptive Flares

Div. F-2 **CH 202**

Juan Diego Carrillo Sánchez	737	Comparative meteoroid fluxes on planetary atmospheres
Annabella Meech	1518	Gaussian processes for high-resolution spectroscopy

Antoine Strugarek	1422	Detectability of magnetic star-planet interactions in compact exosystems
Gulchehra Kokhirova	400	New Near-Earth Objects in the Taurid complex

Div. G-2 **CH 106**

Lisa Bugnet	2712	PhD Prize Talk: Characterization of solar-type stars and study of their internal magnetic fields along the evolution: Machine learning for asteroseismology and theoretical constraints for internal magnetic fields
Allan Sacha BRUN	1231	On convection and gravity waves in F stars
Junho Park	612	Shear instabilities and turbulence in radiation zones of rotating stars
Christopher Tout	2310	A double magnetic dynamo in cataclysmic variables

Div. H-2 **CH 109**

Cecilia Bacchini	2607	Star formation laws and gas turbulence in nearby galaxies
Martin Bureau	2727	WISDOM: Molecular cloud properties and star-formation quenching
Eva Schinnerer	2726	A cloud-scale view of the star formation process
Tony Wong	2207	The 30 Doradus Molecular Cloud as Revealed by ALMA
Shanghuo Li	1541	Binary Formation in the Massive Cluster-formation Region

Div. J-2 **CH 205**

Xiaohui Fan	2295	Quasars and the intergalactic medium at cosmic dawn
Jorryt Matthee	2641	(Re)solving Reionization with Lyman-alpha emission
Yongjung Kim	1855	Discovery of Two New z~6 Quasars with IMS and Space Density down to M1450 ~ -23.5 mag
Yongmin Yoon	589	Bar Formation and Star Formation Enhancement in Disk Galaxies in Interacting Clusters
M. James Jee	2425	Tracing the origin of intracluster stars with Horizon Run 5

Break 15:00-15:15

Afternoon Oral Session 2 15:15-16:45, Convention Hall

Name	Abs. No.	Title

Div. A-3 **CH 103**

Div. B-3			**CH 101**
Douglas Bock	2833	Transforming our knowledge of the radio sky with ASKAP	
Bruce Berriman	1040	Enabling Science with Virtual Observatory	
Anthony Beasley	858	Satellite interference with radio interferometers - on-sky testing and new mitigation schemes	
Constance Walker	896	The impact of satellite Constellation on optial astronomy: the issues and mitigation solutions	
Discussion			

Div. C-3			**CH 104**
Cintia Durán	2893	SPACE LIBRARIES: How to use multidisciplinary approaches to reach vulnerable communities through planetary sciences and literature.	
Jielai Zhang	1950	PASEA: Inspiring Future Astronomy Leaders in Africa	
Akihiko Tomita	853	Launch of the new Astronomy Day in Schools (ADiS) and its results to date	
Hassan Baghbani	2116	Teachers' International Network for Astronomy (TINA)	
Mahdi Rokni	863	Students' International Network for Astronomy (SINA); Overview and the future	
Magdalena Kersting	2719	General Relativity in Secondary School - Research-Based Development of Learning Resources and Analyses of Students' Conceptual Understanding	

Div. D-3			**CH 201**
Mathieu Renzo	3111	What is the maximum mass of stellar mass black holes?	
Renuka Pechetti	649	An IMBH in the most massive globular cluster of M31	
Przemek Mroz	979	Searching for intermediate-mass black holes with gravitational microlensing	
Roberto Soria	1959	X-ray searches for intermediate-mass black holes in the local universe	

Div. E-3			**CH 108**
Valentin Martinez-Pillet	2821	Recent Instrumentation: Science and Status	
Aleida Higginson	2814	A Whirlwind Tour of the Corona-Solar Wind Connection: Science and Status	
Sarah Gibson	461	The Science of PUNCH	
Durgesh Tripathi	717	Science Objectives of Aditya-L1	

Div. F-3 **CH 202**

Tim Lichtenberg	2028	Geophysical Evolution During Rocky Planet Formation
Raissa Estrela	2535	Exoplanets Atmospheres and Habitability
Lev Tal-Or	2077	Analysis of the public HARPS/ESO spectroscopic archive: Jupiter-like planets around HD 103891 and HD 105779

Div. G-3 **CH 106**

Merieme Chadid	3023	First detection of gravity modes in RR Lyr stars
Vardan Elbakyan	1527	Accretion bursts in high-mass protostars
Elnaz Bakhshi	2852	THE FIRST PHOTOMETRIC STUDY OF AH MIC CONTACT BINARY SYSTEM

Div. H-3 **CH 109**

Anirudh Chiti	3452	Mapping the Ancient Milky Way and its Relic Dwarf Galaxies
Claude Carignan	752	Evidence of ram pressure stripping of WLM, a dwarf galaxy far away from any large host galaxy
Wanggi Lim	1410	Tracing dominant shock mechanisms of Orion A
Denise R. Gonçalves	2507	Innovating the Hunter Techniques: RAMSES II - RAMan Search for Extragalactic Symbiotic Stars
Sun Kwok	1054	Synthesis and distribution of complex organics by planetary nebulae

Div. J-3 **CH 205**

Brenda Namumba	376	HI mapping of nearby dwarf galaxies with SKA pathfinders: unique capabilities of KAT-7 and MeerKAT
Johan Comparat	2412	The cosmic web of galaxies seen in X-ray by eROSITA
Hyungjin Joo	1989	Intracluster Light Study of the Galaxy Clusters at z > 1 with Hubble Space Telescope WFC3/IR Data
Dominik Riechers	1537	Water Silhouettes against the Cosmic Microwave Background from the Most Distant Starburst Galaxies
Haeun Chung	1943	Nox: 12U CubeSat Mission Concept for Characterizing All-Sky FUV Background

Afternoon e- Poster 16:45-17:30, Grand Ball Room

Coffee Break 16:45-17:30, Grand Ball Room

Public Lecture 1	19:00-20:30, Auditorium
Sheperd S. Doeleman	Imaging a Supermassive Black hole

Day 5_August 6 (Sat)

Public Lecture 2	17:30-19:30, Auditorium
Brian P. Schmidt	The State of the Universe

Day 6_August 8 (Mon)

Morning Plenary 08:15-09:45, Auditorium

Name	Abs. No.	Title
IAUS 370		
Stanley Owocki	2488	Winds and magnetospheres from stars and planets: similarities and differneces

Morning e- Poster 09:45-10:30, Grand Ball Room

Coffee Break 09:45-10:30, Grand Ball Room

Morning Oral Session 10:30-12:00, Convention Hall

Name	Abs. No.	Title
Div. A-4		**CH 103**
Div. B-4		**CH 101**
Paul Barklem	954	Laboratory Astrophysics - present and future
Dongsu Ryu	1868	Laboratory Astrophysics in Korea
Beatriz Barbuy	3109	A preliminary survey of Laboratory Astrophysics in South America
Peng Kian Tan	1038	Quantum Sensing for Astronomy
Naoki Watanabe	1077	Activities of Laboratory Astrophysics in Japan
Farid Salama	3467	Laboratory Astrophysics in the US
Paul Barklem	3468	Laboratory Astropysics in Europe
Div. C-4		**CH 104**
Alejandro Martín López	2156	Tales about the sky. Orality and mythical analysis in cultural astronomy
Thilina Heenatigala	1397	Perspectives on Decolonising Astronomy for an Inclusive Environment
Leinani Lozi	2811	Hawai'i Astronomy: Traditional and Modern Methods
Aniket Sule	741	Astronomical skills of fishing communities in Western India
Steven Gullberg	600	Listening to Other Voices: Culturally Sensitive Sites Committee
Michael Burton	410	Ireland's Historic Observatories and their intersection with science, culture and politics

Div. D-4 — CH 201

Riccardo Arcodia	3110	Accretion onto black holes across the mass scale
Ilje Cho	637	Unveiled properties of the supermassive black holes with the Event Horizon Telescope
Eckhard Sturm	934	Supermassive black hole mass estimates from interferometric spectro-astrometry and reverberation mapping
Shu Wang	1988	Investigating the high-luminosity end of the H-beta size-luminosity relation based on the 6-year Seoul National University Monitoring Project
Thomas Connor	638	Growing the First Supermassive Black Holes

Div. E-4 — CH 108

Gopal Hazra	2840	Understanding the Behaviour of the Sun's Large Scale Magnetic Field and its Relation with the Meridional Flow
Souvik Bose	3116	On the Dynamics of Spicules and Mass-Flows in the Solar Atmosphere
Reetika Joshi	3117	Study of Solar Jets and Related Flares
Prantika Bhowmik	1764	Data Constrained Models for Solar Activity Predictions
Camilla Scolini	325	Evolution of Interplanetary Coronal Mass Ejections and their Space Weather Impact throughout the Inner Heliosphere: A Modeling Perspective
Munehito Shoda	1865	Three-Dimensional Simulation of the Fast Solar Wind: The Role of Parametric Decay Instability
Jenna Samra	2723	High-Altitude Instrumentation for Infrared Observations of the Solar Corona

Div. F-4 — CH 202

Maria Drozdovskaya	1596	Chemical complexity from star-forming regions to comets
Luca Fossati	530	Exoplanet atmospheric escape: theory and observations
Sun Kwok	1052	Enrichment of the primordial Solar System by stellar organics

Div. G-4 — CH 106

Simon Blouin	2745	Decoding the white dwarf fossil record
Natalia Lewandowska	2363	Disentangling the mysteries of single pulses from the Crab pulsar
Taeho Ryu	2598	Fully relativistic global simulation of a tidal disruption event
Bonnie Zaire	309	What does control the large-scale magnetic field configuration of cool stars?

Div. H-4		**CH 109**
David Valcin	2491	Precision age dating of globular clusters
Deokkeun An	1123	A Blueprint for the Milky Way's Stellar Populations
Jihye Hwang	572	A Spiral Magnetic Field in a Hub-Filament Structure, Monoceros R2
M. Belen Mari	2930	New insights into low-ionization structures in planetary nebulae through statistical analysis
Ting Li	1812	The Orbital and Chemical Properties of One Dozen Stellar Streams from the Southern Stellar Stream Spectroscopic Survey

Div. J-4		**CH 205**
Solène Chabanier	2750	Neutrino and dark matter cosmology with the Lyman-alpha forest
Hamsa Padmanabhan	2883	New empirical constraints on the cosmological evolution of gas and stars in galaxies
Hannah Stacey	687	Dusty quasars eject star-forming gas from galaxies at cosmic noon
Gyula I. G. Józsa	1498	Results from the MeerHOGS

Lunch Break 12:00-13:30

Woman in Astronomy Lunch 12:00-13:30, Hall 5A, Exhibition Center II

Afternoon Oral Session 1 13:30-15:00, Convention Hall

Name	Abs. No.	Title
Div. A-5		**CH 103**

Div. B-5		**CH 101**
Marie Lise Dubernet		WG Actvities and Plans
Marie Lise Dubernet	762	Laboratory Astrophysics Databases: from the provider to the user: encouraging FAIRness
Bruce Berriman	1042	FAIR principles in IVOA
Christiaan Boersma	436	The NASA Ames PAH IR Spectroscopic Database
Cornelia Jäger	2188	Laboratory Astrophysic Databases on grains and ices: from the laboratory to the Users
Miriam Rengel	2715	About the atomic and molecular databases in the planetary community
Will Robson Monteiro Rocha	813	ENIIGMA: A Python package for ice spectral decomposition of protostars

Div. C-5 CH 104

Nilson Moreira da Silva	2897	OruMbya - Astronomy as fuel of life: the resilience of stars in Yoruba, Afro-Brazilian and Indigenous Cosmogony.
Paulo Sergio Bretones	2340	Astronomy in schools: science, history and culture together
Jaeil Cho	1930	Performance and application of the radio telescope in Gwacheon National Science Museum
Deborah Kala Perkins	315	Between Cosmology and Consciousness: Fathoming of the Fabric of the Infinite at the Nexus of Ancient and New Cosmologies
David Barrado	3462	COSMOGRAPHY: THE SCIENCE O THE TWO ORBS. THE ROLE OF AL-ANDALUS
Maria Giulia Andretta	251	The conquest of the Moon. The history, the legacies and the cultural influence of the Moon landing. Analysis of the Italian media phenomenon as an example of pop science

Div. D-5 CH 201

Vardha N. Bennert	641	Supermassive Black Holes and their Host Galaxies
Guang Yang	250	What drives the growth of black holes?
Kohei Inayoshi	1012	The assembly of the first massive black holes and the prospects of upcoming observations
Sarah Vigeland	607	Supermassive Black Holes and Merging Galaxies: Low-Frequency Gravitational Wave Detection with Pulsar Timing Arrays
Vasyl Ponomarenko	2080	Results of optical research of selected active galactic nuclei

Div. E-5 CH 108

Manuela Temmer	354	Large-Scale Structures in the Heliosphere and their Space Weather Impact
Mathew Owens	964	Space Weather Across the Time Scales: Minutes to Millennia
Ilya Usoskin	655	Do We Understand the Physics of Extreme Solar Events?
Devojyoti Kansabanik	396	Recent Developments in Space Weather Research with High Fidelity Low-Frequency Spectro-Polarimetric Imaging Using SKA-Low Precursor
Hee-Eun Kim	593	Heating of Ions at the Supercritical and Subcritical Quasi-perpendicular Earth's Bow Shocks

Div. F-5 CH 202

Shogo Tachibana	2226	What We Have Learned from Samples Returned from C-type Near-Earth Asteroid (162173) Ryugu

Masatoshi Hirabayashi	985	YORP-driven structural and rotational interactions of irregularly shaped rubble pile asteroids
Yaeji Kim	860	Numerical investigation of how (486958) Arrokoth's structure did respond to the sky impact
Yeva Gevorgyan	1280	Comparison of Stratified and Effective Rheological Models For Icy Worlds

Div. G-5 **CH 106**

Steven Goldman	1748	A Census of Thermally-Pulsing AGB stars in the Andromeda Galaxy and a First Estimate of their Contribution to the Global Dust Budget
Jielai Zhang	2329	Kilonova and fast transients - an untriggered search
Melike AFSAR	1758	Unveiling effective temperatures using line depth ratios in the infrared H and K bands
Kelly Hambleton	2512	The Transients and Variable Star science collaboration roadmap explained

Div. H-5 **CH 109**

Victor Robles	3293	Constraints to the dark matter nature from the internal structure and orbital pericenters of Milky Way Satellites
Giseon Baek	1594	Complex organic molecules detected in twelve high-mass star-forming regions with Atacama Large Millimeter/submillimeter Array (ALMA)
Giang Nguyen Chau	2240	Modeling Polarized Thermal Emission from Dust Grains with Iron Inclusions Aligned by Radiative Torques in Low-Mass Protostellar Cores
Jeongkwan Yoon	1857	Ratio Tables of Chemical Species at Equilibrium for Primordial Chemistry
Beatrice Kulterer	1577	Constraints on methanol deuteration in prestellar cores
Siek Hyung	2572	Density Derivation by Nebular and Auroral/Nebular Lines Ratios

Div. J-5 **CH 205**

Cristina Popescu		Vice-President, Divison J
Andrew Battisti	787	Sharpening our View of Dust Attenuation using the TYPHOON survey
Ismael Ferrero	518	A Unified Scenario for the Origin of Spiral and EllipticGalaxy Structural Scaling Laws
Hyein Yoon	1555	Searching for extragalactic HI 21-cm absorption: Early results from the ASKAP-FLASH pilot observations
Ryan Keenan	1935	Tools for Measuring the Cosmic Molecular Gas History
Brianna Smart	689	The Diffuse Ionized Gas of the Magellanic System

Break		15:00-15:15

Afternoon Oral Session 2		15:15-16:45, Convention Hall
Name	Abs. No.	Title
OAO-4		**CH 101**
Pedro Russo	3428	The Public Value of Astronomy
Oana Sandu (Barbulete)	2976	Commission C2 and its strategic role within the IAU and beyond
Discussion		
OAD-4		**CH 205**
Kevin Govender		Overview
Alemiye Mamo Yacob	1570	Global structure in astronomy-for-development: a case of East African Region
Awni Kasawneh	1327	Space Activities, Laws, and Regulations in the Arab World
Michelle Willebrands	432	Activities of the IAU E-ROAD and its flagship project Pale Blue Dot
Nnaemeka Onyeuwaoma	433	West African Regional Office of Astronomy for Development: The Journey So Far
Prospery Simpemba	2211	Overview of Astronomy projects in Southern Africa
Rosa Doran	2787	The Road towards Astronomy for Development in Portuguese Speaking Countries
Discusssion		
Giovanni Pinzon	3045	Overview of activities of Andean Regional Office of Astronomy for development
Supaluck Chanthawan	3046	Astronomy for Development in CLMV and Beyond
Areg Mickaelian	3047	IAU South West and Central Asia ROAD: Recent Activities
Tim Spuck	3048	Reaching for the Stars with the North American Regional Office of Astronomy for Development
Discusssion		
OAE-4		**CH 103**
Jungjoo Sohn	3422	OAE Node Korea: Our past and future
Abd El Fady Morcos	2147	Development plan for Astronomy Education in Framework of OAE -Center Egypt

OYA-4			**CH 104**
Paulo Sergio Bretones	2959	Astronomy Education Studies in the ISYA programs	
Discusssion			
WG 1-1			**CH 202**
Lina Canas	2960	Astronomy for Equity, Diversity and Inclusion - a roadmap to action within the framework of the IAU centennial anniversary	
Susana Deustua		The recommendations of the Springboard to Action	
Discusssion			
WG 2-1			**CH 108**
Rachel Osten		Coordination of Large Space Missions	
Matthew Colless		Coordination of Large Ground-based Facilities	
Ewine van Dishoeck	2336	Synergies of ground- and space- astronomy	
WG 3-1			**CH 106**
Johan Knapen	2421	Scientific Writing for Astronomers: Choice of journal, Submission process, and Writing guide	
Nushkia Chamba	2631	Scientific Writing for Astronomers: From Thinking to Paper Outline	
WG 4-1			**CH 109**
Ewine van Dishoeck	2337	Women in astronomy and the IAU: past, present and future	
Silvia Torres Peimbert	2495	Women participation in Latin America astronomy	
Annapurni Subramaniam	3132	Career stories, problems, and efforts in India to achieve gender balance in Astronomy	
Suzana Filipecki Martins	3133	STI Indicators and the Design of the 2022 Edition of Women and Girls In Astronomy IAU Global Outreach Project	
Jolanta Nastula	1439	Gender balance in CBK PAN	

Afternoon e- Poster	16:45-17:30, Grand Ball Room
Coffee Break	16:45-17:30, Grand Ball Room

Afternoon Oral Session 3

17:30-19:00, Convention Hall

IAU Offices — CH 205

Name	Abs. No.	Title
Debra Elmegreen		Introductory remarks
Kateryna Frantseva	2642	Overview of the IAU fundraising efforts
Vanessa McBride	3049	Collaborations and partnerships within and outside IAU
Discusssion		
Diana Worrall		Concluding remarks

WG 1-2 — CH 202

Name	Abs. No.	Title
Rachael Beaton	2139	Diversity, Equity, & Inclusion in Large Collaborations: A Decade of Work in the Sloan Digital Sky Survey-IV
Anna Voelker	2777	AstroAccess: Advancing research on accessibility to prepare for diverse needs in human spaceflight activities
Jeong Ae Lee	395	Let's go to the Universe, TOGETHER! - with Hearing-impaired children
Round Table		

WG 2-2 — CH 108

Name	Abs. No.	Title
Discusssion		Coordination of Large Space Missions
Laura Kreidberg		Global coordination for the next decade of science: Exoplanets
Scott Trager	654	Global coordination of stellar and stellar population spectroscopy in current and future spectroscopic surveys
John Silverman		Global coordination for the next decade of science: Black Holes
Ofer Lahav		Global coordination for the next decade of science: Cosmology

WG 3-2 — CH 106

Name	Abs. No.	Title
Lina Canas	2907	IAU Outreach: Building Bridges Through Communication and International Cooperation

WG 4-2 — CH 109

Name	Abs. No.	Title
Mamta Pommier	1060	IAU Women in Astronomy WG activities and survey results
Jeong-Eun Lee	3134	Women is Astronomy division of Korean Astronomical Society

Tony Travouillon	3135	ANU Research School of Astronomy and Astrophysics Advanced Instrumentation Technology Centre (AITC) women-only recruitment strategy and objectives?
Eleni Chatzichristou	3449	ERC Measures and Practices to Improve Gender Balance in Science

Day 7_August 9 (Tue)

Morning Plenary — 08:15-09:45, Auditorium

Name	Abs. No.	Title
IAUS 371		
David Devorkin	1721	Turning Chaos into Order: The Life and Work of Charlotte Moore Sitterly
Alexander Kramida	1234	The Legacy of Charlotte Moore Sitterly in the Internet Age

Morning e- Poster — 09:45-10:30, Grand Ball Room

Coffee Break — 09:45-10:30, Grand Ball Room

Morning Oral Session — 10:30-12:00, Convention Hall

Name	Abs. No.	Title
IAUS 370-1		**CH 101**
Rachel Osten	2751	Observations of winds and CMEs of low-mass stars
Grace Telford	1806	FUV Constraints on the Winds and Rotation of Main-Sequence O Stars at Extremely Low Metallicity
Simon Daley-Yates	828	Slingshot Prominences, Formation, Ejection and Cycle Frequency in Cool Stars
Calum Hawcroft	2864	New empirical mass-loss rates and wind properties of massive stars at low metallicity
Gemma González-Torà	283	The effect of winds in Red Supergiants I. 1D Modelling for interferometric observations
IAUS 371-1		**CH 202**
Ewine Van Dishoeck	2335	Molecular processes relevant for astrophysics: theoretical studies
Alexandre Faure	3004	Collisional rate coefficients for astrophysics
IAUS 373-1		**CH 205**
Sebastian Francisco Sanchez Sanchez	3016	The local and global relations between Σ*, Σ_SFR and Σ_mol that regulate star-formation
Catherine Zucker	2621	Supernova-Driven Star Formation in the Milky Way

Kazuki Tokuda	2624	ALMA resolved views of molecular filaments/clumps in the Large Magellanic Cloud: A possible gas flow penetrating one of the most massive protocluster systems in the Local Group
Amy Miller	2808	Turbulence-Controlled Hierarchical Star Formation in the Large Magellanic Cloud
Jin Koda	1877	Abundant Molecular Cloud Cores with Photo-Dissociated Envelopes Discovered in the XUV Disk of M83 with ALMA
Sarah Jeffreson	2190	A sub-grid model for the molecular cloud lifecycle

IAUS 374-1 **CH 104**

Jeffrey Love	2446	Down to Earth with geoelectric hazards from space
Ihor Kyrylenko	2869	Orbit and dynamic origin of the recently recovered iron meteorite
Gulchehra Kokhirova	346	ASTEROID APOPHIS AND ITS ASSOCIATED FIREBALLS
Svitlana Kolomiyets	2791	The meteoroid component of the astronomical hazard to Life on Earth: contribution, relationships and more

FM 1-4 **CH 109**

Susumu Inoue	2923	Gamma-ray bursts and their outflows: physics and implications of very high energy emission
Bestin James	2009	Modeling the GRB jet properties with 3D general relativistic simulations of magnetically arrested accretion flows
David Russell	2401	Universal magnetic field properties in relativistic jets from accreting objects
Mark Birkinshaw	1204	PKS 2152-699: jet coherence after strong jet-cloud interactions
Kohei Ichikawa	678	Rapidly growing supermassive black holes in extremely radio-loud galaxies
Shifu Zhu	276	The origin of X-ray emission from most radio-loud quasars

FM 2-4 **CH 103**

Constance Walker	895	Overview of the impacts from and mitigations of satellite constellations on optical astronomy
Federico Di Vruno	2320	Large LEO satellite constellations: Prospects for interference and threats to radio astronomy
Olivier Hainaut	1601	Quantifying the effect of satellite constellations on optical observations
Gyula I. G. Józsa	1493	The Opticon-Radionet effort towards the protection of the dark and quiet skies
Discussion		

Piero Benvenuti	690	The IAU Centre for the Protection of Dark and Quiet Sky from Satellite Constellations Interference (IAU CPS)
Siegfried Eggl	2227	SatHub - A Community Driven Observation Portal of the new IAU Centre for the Protection of the Dark and Quiet Sky from Satellite Constellation Interference
Jonathan McDowell	1070	Software needs to mitigate the satellite constellation challenge

FM 10-4 **CH 106**

Ashish Mahabal	1228	Searching Solar System and Exoplanetary Bodies the Data Science Way
Jean-Eudes Arlot	1710	NAROO: a New Astrometric Reduction of Old Observations
Teymoor Saifollahi	1695	Precovery and risk assessment of the hazardous Near-Earth Objects in large astronomical surveys
Svitlana Kolomiyets	1232	Data docking in meteor research

WG 1-3 **CH 108**

Santiago Vargas Domínguez	3438	Astronomy breaks barriers and connects people
Steven Gullberg	3436	HERITAGE, INDIGENOUS PEOPLES, AND ASTRONOMY
Annette Lee	2341	"Working at the Intersection of Art, Science, and Culture for the Benefit of All"

Lunch Break 12:00-13:30

Afternoon Oral Session 1 13:30-15:00, Convention Hall

Name	Abs. No.	Title

IAUS 370-2 **CH 101**

Andrea Mehner	1053	Observations of outflows of massive stars
Atefeh Javadi	2775	Mass-loss rates of cool evolved stars in the Local Group galaxies
Leonardo Dos Santos	1595	A review on the observations of planetary winds and outflows
Hyosun Kim	2096	The porous envelope and circumstellar wind matter of the closest carbon star

IAUS 371-2 **CH 202**

Marie Lise Dubernet	763	Databases of atomic and molecular data
Will Robson Monteiro Rocha	808	LIDA: The Leiden Ice Database for Astrochemistry

Yuri Ralchenko	2534	NIST-LANL Lanthanide Opacity Database

IAUS 373-2 **CH 205**

Kazuo Sorai	702	Molecular Gas Contents and Star Formation Efficiency in Local Galaxies
Barbara Catinella	2866	The link between cold gas global reservoirs and star-formation activity in galaxies
Erwin De Blok	1138	First results from the MHONGOOSE ultra-deep MeerKAT HI survey of nearby galaxies
GYUEUN PARK	1479	Probing the Conditions for the Atomic-to-Molecular Transition in the Interstellar Medium
Hsi-An Pan	467	Gas-Star Formation Cycle in Nearby Galaxies
Bruce Elmegreen	472	A Search for correlations between turbulence and star formation in LITTLE THINGS and THINGS galaxies

IAUS 374-2 **CH 104**

Brent Barbee	2667	The Opportunity to Defend Ourselves Against Near-Earth Object Impact Threats
Richard Wainscoat	1076	The Pan-STARRS search for Near-Earth Objects (NEOs)
Suresh Bhattarai	2688	Asteroid Search Program: An Initiative To Engage People for The Protection of Planet Earth
Xuguang Leng	874	Jupiter and Evolution of Complex Life on Earth

FM 1-5 **CH 109**

Dipanjan Mukherjee	336	Simulating young evolving relativistic jets from supermassive black holes
Maccagni Filippo	1751	Jets and ISM interplay from the nucleus to the outskirts: the two cases of Centaurus A and Fornax A
Motoki Kino	750	Witnessing the moments of jet-cloud collisions in the young radio galaxy 3C84
Joana Kramer	452	Ray-Tracing in Hybrid Relativistic Magnetohydrodynamic Jet Simulations: A Polarimetric Study
Francoise Combes	596	Jet-ISM interaction: observations

FM 2-5 **CH 103**

Richard Green	832	National Policy and Regulations
Discussion		

Tim Stevenson	2633	The Industry hub of the IAU Centre for the Protection of the Dark and Quiet Sky
Jessica Heim	2531	Community Engagement
Fatoumata Kebe	859	Educating and empowering astronomers with SatHub
Priya Shah	529	Dark Skies and Bright Satellites
Discussion		

FM 10-5 **CH 106**

Marco Micheli	619	High precision astrometry of small solar system bodies
Matthew Lehner	2732	The Transneptunian Automated Occultation Survey – TAOS II
Julia de León	2013	Understanding asteroids from their spectra. Asteroid taxonomies: benefits and limitations
Ivan Slyusarev	2411	Search for M-type dominated asteroid families
Said Hmiddouch	1478	Composition and activity of comets with TRAPPIST telescopes

WG 1-4 **CH 108**

Simona Mei	3437	Discrimination, bullying and harassment in STEM
Discussion		

Break 15:00-15:15

Afternoon Oral Session 2 15:15-16:45, Convention Hall

Name	Abs. No.	Title

IAUS 370-3 **CH 101**

Susanna Parenti	2281	Updates on recent findings from the solar wind with major facilities
Gopal Hazra	2278	Effect of stellar coronal mass ejections and flares on the atmosphere of hot Jupiters and their transit signatures
Giovanni Pinzon	1028	Is the magnetospheric accretion process active in Herbig Ae/Be stars ?
Marina Rumenskikh	335	Interpretation of transit absorptions in the atmosphere of HD-189733b
Kristina Kislyakova	2585	X-ray observations as a tool to estimate stellar mass losses

IAUS 371-3 **CH 202**

Maria Bergeman	1981	The state of solar analyses, and solar and stellar spectroscopy and solar models

Gloria Canocchi	1629	Improving planetary atmosphere characterization by 3D NLTE modeling of the stellar centre-to-limb effect
Terese Olander	2611	Comparative high-resolution spectroscopy of M dwarfs: Exploring non-LTE effects
Abdelmajid Benhida	1135	Contribution of small telescopes at the Oukaimeden Observatory in Morocco to study Atmospheric dynamics and shocks in variables stars RR Lyr and R sct

IAUS 373-3 **CH 205**

Aeree Chung	1881	The impact of ICM ram pressure on the cool gas content and SF activity of galaxies
Zhiyu Zhang	2886	Dense molecular gas tracers in nearby galaxies
Jiayi Sun	451	Molecular Cloud Populations in the Context of Their Host Galaxies: Insights from PHANGS-ALMA
Ayu Konishi	744	Exploring the evolution of giant molecular clouds in one of the nearest spiral galaxies M33
Gerhard Hensler	834	Conditioning star formation in intergalactic clouds
Zara Randriamanakoto	1566	The SUNBIRD Survey: insights into small-scale star formation mechanisms through the NIR study of young massive clusters in a sample of starburst and luminous infrared galaxies

IAUS 374-3 **CH 104**

Patrick Michel	1168	The ESA Hera mission to the binary asteroid Didymos: NEO deflection investigation and full characterization
Thomas Statler	2089	After DART: Informing a Hypothetical Future Asteroid Deflection with Results from the First Kinetic Impactor Test
Vasiliki Petropoulou	2066	The EU H2020 project "NEOROCKS -The NEO Rapid Observation, Characterization and Key Simulations"
Simone Ieva	2032	OBSERVATIONAL CHARACTERIZATION FOR THE DIDYMOS SYSTEM IN SUPPORT OF THE DART & LICIACUBE MISSION, THE FIRST KINETIC IMPACTOR DEMONSTRATION
Elisabetta Dotto	1795	LICIACube: the Light Italian Cubesat for Imaging of Asteroids part of the NASA mission DART

FM 1-6 **CH 109**

Andrew Fabian	1691	Jet-ICM interaction
Filippo D'Ammando	1813	Unveiling the physics of relativistic jets with LSST and CTA

Maria J. Rioja	2426	New Opportunities with Next-Generation Instruments: SKA and Millimetron
Ulisses Barres de Almeida	1432	Potential for Very High Energy gamma-ray transient monitoring with SWGO
Gabriele Giovannini	533	Concluding Remarks

FM 2-6 **CH 103**

Jeremy Tregloan-Reed	2174	Optical and NIR magnitude measurements of Low Earth Orbit satellites, from a global observing network
Angel Otarola	1343	Observations, analysis and characterization of satellites in Low Earth Orbit mega-constellations
Przemek Mroz	975	Impact of LEO Megaconstellations on the Zwicky Transient Facility Survey Observations
Bevin Vanderley	2890	Impacts to U.S. Ground-based Astronomical Facilities
Olga Zamora	714	The brightness and colors of Oneweb satellites
Svitlana Kolomiyets	1264	On the space debris component in meteoroid models
Discussion		

FM 10-6 **CH 106**

Josef Durech	2396	Asteroid photometry and its interpretation
Eric MacLennan	1120	Significance of shapes and spins in the thermophysical modeling of asteroids
Alberto Cellino	2391	Asteroid Polarimetry in the Gaia Era
Hee-Jae Lee	1460	Light curve survey of the asteroids with KMTNet
Gulchehra Kokhirova	390	Synergy of Small Telescopes for Asteroid (6478) Gault Observations in Tajikistan and Slovakia

WG 2-3 **CH 108**

Afternoon e- Poster 16:45-17:30, Grand Ball Room

Coffee Break 16:45-17:30, Grand Ball Room

Conference Dinner 17:30-19:30, Hall 5A, Exhibition Center II

Day 8_August 10 (Wed)

Morning Plenary 08:15-09:45, Auditorium

Name	Abs. No.	Title
IAUS 373		
Adam Leroy	3017	Star Forming Galaxies Resolved into their Fundamental Units
Annalisa Pillepich	2165	Star formation across the bodies of galaxies and its suppression: a theoretical overview
Yingjie Peng	634	Exploring star formation and quenching via observations, simulations and synergies

Morning e- Poster 09:45-10:30, Grand Ball Room

Coffee Break 09:45-10:30, Grand Ball Room

Morning Oral Session 10:30-12:00, Convention Hall

Name	Abs. No.	Title
IAUS 370-4		**CH 101**
Daria Kubyshkina	1214	The origin of planetary winds
Dualta O Fionnagain	2626	Coronal Mass Ejections and Type II Radio Emission Variability during a Magnetic Cycle on the Solar-type Star ϵ Eridani
Jorick Vink	848	Theory and Diagnostics of hot star mass loss
Hiroto Mitani	1960	The classification of the atmospheric escape: three types of escape driven by EUV photoionization heating
Florian Driessen	1392	Discrete Absorption Components' from 3-D spot models of hot star winds
IAUS 371-4		**CH 201**
Christian Clear	2271	Atomic data from the UV to the IR
Maria Teresa Belmonte	2484	Accurate new atomic data needed for Galactic Surveys
Milan Ding	665	New Laboratory Atomic Data for Neutral, Singly and Doubly Ionised Iron Group Elements for Applications in Astrophysics
IAUS 373-4		**CH 205**
Bianca Poggianti	660	Star forming clumps, rates and histories: the spatially resolved view in dense galaxy environments

Ji-hoon Kim	324	324 How Feedback Affects Stellar and Galactic Evolution: Perspectives in the Era of High-resolution Simulations
Jeong-Gyu Kim	2785	Relative importance of different stellar feedback processes in dispersal of giant molecular clouds
Di Wang	1378	The SAMI Galaxy Survey: Using concentrated star formation and stellar population ages to understand environmental quenching
Camila De Sá Freitas	337	Quenching, bursting and galaxy shapes: colour transformation as a function of morphology
Yuri Oku	983	Osaka feedback model II: Modeling supernovae based on high-resolution simulations

IAUS 374-4 **CH 104**

Rosita Kokotanekova	715	We do look up: what cometary science has revealed about the potential hazards of comet and interstellar object impacts
Makoto Yoshikawa	2515	Planetary defense activities at JAXA
James (Gerbs) Bauer	1771	The Many Comets of NEOWISE
Camilo Delgado-Correal	2788	Optimization of Gauss Method to describe with most accuracy the orbits of Near Earth Asteroids - NEAs

FM 3-1 **CH 103**

Marika Asgari	575	Cosmic Shear Analyses with KiDS: past, present and future
Alexandra Amon	3122	Cosmology from DES Y3 weak lensing
Hironao Miyatake	3123	Weak Lensing Cosmology from Subaru Hyper Supreme-Cam Survey

FM 6-1 **CH 106**

Melanie Johnston-Hollitt	1079	The Importance of Wideband Spectral Observations of Radio Emission in Galaxy Clusters
Ruta Prabhakar Kale	2200	Revealing properties of non-thermal emission from galaxy clusters using the Upgraded GMRT
Reinout Van Weeren	2409	LOFAR observations of the Perseus Cluster
Christian Groeneveld	1805	Galaxy clusters in the Decameter Sky
Gianfranco Brunetti	2171	Tackling the complexity of non-thermal phenomena in galaxy cluster sand LSS

FM 7-1 **CH 109**

Lennart Lindegren	943	21st Century Astrometry and its Science Applications

Rachael Beaton	2135	The 21st Century Challenge of Distances: More Robust, Faster, and Farther
Alex Golovin	2847	The Fifth Catalogue of Nearby Stars (CNS5): catalogue construction, completeness, and luminosity functions
Gordian Edenhofer	1050	The Galactic 3D large-scale Distribution of Dust from Astrometric Data
Minia Manteiga	1540	Galactic Planetary Nebulae central stars properties and binarity from Gaia EDR3 astrometry and photometry

WG 2-4 **CH 108**

Lunch Break 12:00-13:30

Shaw Prize Lecture 12:15-13:15, Auditorium

Lennart Lindegren	Gaia and global space astrometry: A historical perspective
Michael Perryman	

Afternoon Oral Session 1 13:30-15:00, Convention Hall

Name	Abs. No.	Title
IAUS 370-5		**CH 101**
Munehito Shoda	1905	Stellar wind from low-mass main-sequence stars: an overview of theoretical models
Catalina Arcos	1612	Hydrodynamic disk solutions for Be stars using HDUST
Robert Kavanagh	976	Signatures of star-planet interactions across the electromagnetic spectrum
Nicolas Moens	1606	Uncovering the Wolf-Rayet wind launching mechanism trough 3D radiation-hydrodynamics
Allan Sacha BRUN	1719	Advanced models of the solar wind, inner corona and heliosphere
IAUS 371-5		**CH 202**
Randall Smith	2948	Precision X-ray spectroscopy
Sonja Bernitt	2366	The Fe XVII 3C/3D Oscillator Strength Problem
Renata Cumbee	2877	Modeling X-ray Emission from Charge Exchange Collisions in Astrophysical Spectra
IAUS 373-5		**CH 205**
Alberto Bolatto	522	Using Observables to Test Models
Lihwai Lin	2307	What drives galaxies from the main sequence to the green valley?

Qingzheng Yu	388	On the HI Content of MaNGA Major Merger Pairs
Yang Sun	1769	Evolution of Bulk Gas Flows from Starburst to Quiescent Galaxies
Martin Bureau	2725	WISDOM: Molecular cloud properties and star-formation quenching
Cressida Cleland	521	Investigating internal and external quenching mechanisms on various timescales

IAUS 374-5 **CH 104**

Heidi Korhonen	2345	Solar hazards on different time scales
Eva Villaver	688	The Fate of planet Earth
Brian Thomas	1035	The Supernova Threat to Life in the Universe
Ammar Abdulla	397	Lunar Impact Events by SLIO in 2020

FM 3-2 **CH 103**

Axel Guinot	2779	Weak Lensing analysis of the 3,600deg2 of the CFIS-UNIONS data
Mijin Yoon	2494	Cosmic shear reanalysis of KiDS-1000 with metacalibration shape catalog
Harry Johnston	1639	Forecasting gains in (4-6)x2pt large-scale structure analyses with spectroscopic-photometric galaxy cross-correlations
Tilman Troester	2071	Can beyond ΛCDM models address the S8 tension? Extended cosmology analysis of the Kilo-Degree Survey

FM 6-2 **CH 106**

Florian Ruppin	1238	High angular resolution SZ cartography of galaxy clusters with NIKA2 at the IRAM 30-m telescope
Charles Romero	1825	The utility of subarcminute SZ observations with MUSTANG-2
Stefania Amodeo	938	Gas thermodynamics from the SZ effects: an ACT view
Luca Di Masco	684	Multi-wavelength view of a massive galaxy cluster merger at z=1.13
Joshiwa Van Marrewijk	1506	RXC-J2014.8-2430, the strongest cool core galaxy cluster in REXCESS: How the hot intracluster medium affects the cold molecular gas in and around the brightest cluster galaxy

FM 7-2 **CH 109**

Sergey Koposov	2117	The stellar streams revolution with Gaia.
Paolo Tanga	2993	The Gaia mission and the Solar System: new perspectives
Daniel Mikkola	471	The velocity distribution of white dwarfs in Gaia EDR3

Lukasz Wyrzykowski	1032	Measuring masses of dark lenses with astrometric microlensing with Gaia
Shuangjing Xu	1568	The Astrometric Animation of Water Masers towards the Mira Variable BX Cam
Tony Sohn	1765	Proper Motions in the Outer Halo and beyond the Milky Way

WG 3-3 **CH 108**

Break 15:00-15:15

Afternoon Oral Session 2 15:15-16:45, Convention Hall

Name	Abs. No.	Title
IAUS 370-6		**CH 101**
Andreas Sander	624	The driving of hot star winds
Takeru Suzuki	872	Role of Longitudinal Waves in Alfven-wave-driven Solar/Stellar Wind
Judy Chebly	2615	Filling the gap in stellar wind observations of cool stars via 3D MHD numerical modelling
Ignacio Araya	1647	ISOSCELES: Grid of stellar atmosphere and hydrodynamic models of massive stars. The first results.
Julián Alvarado-Gómez	414	Simulating the Space Weather in the AU Mic System: Stellar Winds and Extreme Coronal Mass Ejections
IAUS 371-6		**CH 202**
Ella Sciamma-O'Brien	2804	Models of Hazes in (exo)planetary atmospheres - The Importance of Producing and Characterizing Laboratory Analogs of (Exo)Planetary Atmospheric Aerosols
Xinting Yu	2908	The Next-Generation Laboratory Experiments on Planetary Materials
Nanae Domoto	2649	Signatures of r-process elements in kilonova spectra
Sema Caliskan	1511	Kilonovae and the cosmic origin of r-process elements: atomic structure and processes of gold
IAUS 373-6		**CH 205**
Miroslava Dessauges-Zavadsky	479	Dissecting the star formation process at molecular cloud scale 8 billion years ago
Itziar Aretxaga	2430	(Sub-)mm continuum surveys: mapping the dusty galaxy contribution to the star formation history

Marcie Mun	1379	Spatially resolving the star formation activity of galaxies at 3 - 4 Gyrs of lookback time with MAGPI
Chelsea Sharon	1061	Characterizing the Resolved Schmidt-Kennicutt Relation Using Different SFR Tracers at Cosmic Noon
Melanie Kaasinen	331	Resolving Star-forming Gas at the Peak Epoch of Star Formation
Po-Feng Wu	650	Understanding quenching at high redshifts from local IFU surveys

IAUS 374-6 **CH 104**

Christopher Impey	1306	How It Ends
Diederik Kruijssen	2133	Introducing the Cosmic Origins Of Life (COOL) model: a multi-scale, multi-physics framework for the emergence and survival of life in a hostile Universe
Gijs Verdoes Kleijn	2016	Piggybacking astronomical hazard investigations on research and development for Big Data science missions
Teymoor Saifollahi	1689	ARE WE SAFE? Precovery and risk assessment of the hazardous Near-Earth Objects

FM 3-3 **CH 103**

Renee Hlozek	1867	CMB tensions and systematics
Sherry Suyu	577	Tensions in Cosmology: H0 measurements
Discussion		

FM 6-3 **CH 106**

Irina Zhuravleva	2590	Updates on Turbulence in Hot ICM
Yuto Ichinohe	525	XRISM observation of galaxy clusters
Eugene Churazov	2045	ICM dynamics in the Coma cluster (X-ray view)
Congyao Zhang	323	Giant shock waves in galaxy cluster
Eunyu Lee	907	Shocks in merging galaxy clusters in cosmological simulations

FM 7-3 **CH 109**

Mark Reid	881	Advances in VLBI Astrometry
Sylvestre	3126	Astrometry of exoplanets with optical interferometry
Laurent Loinard	1824	VLBI astrometry in the epoch of Gaia
Megan Johnson	3425	Writing grant and observing proposals: sharing my ESO and ERC experience.

Lucas Hunt	2702	Comparing Images of ICRF Sources at S, X, K and Q-band
Phil Cigan	1097	Three years of ICRF3 source positions

WG 3-4 **CH 108**

Richard de Grijs	2261	Writing grant proposals: Your road to success
Vincenzo Mainieri	2639	Writing grant and observing proposals: sharing my ESO and ERC experience

Afternoon e- Poster 16:45-17:30, Grand Ball Room

Coffee Break 16:45-17:30, Grand Ball Room

Invited Discourse 3 17:30-18:30, Auditorium

Hiroyuki Maehara — Superflares and super coronal mass ejections on solar-type stars

Day 9_August 11 (Thu)

Morning Plenary		08:15-09:45, Auditorium
Name	Abs. No.	Title
IAUS 374		
Milan Cirkovic	3453	Rare Earth Got It Wrong: Astronomical Hazards and Habitability

Morning e- Poster	09:45-10:30, Grand Ball Room
Coffee Break	09:45-10:30, Grand Ball Room

Morning Oral Session		10:30-12:00, Convention Hall
Name	Abs. No.	Title
IAUS 370-7		**CH 101**
Jonathan Mackey	1335	Interaction between massive star winds and the interstellar medium
Eva Villaver	686	Stellar winds and the survival of planets
Ildar Shaikhislamov	342	Interaction of exoplanetary and stellar winds and its observational manifestations
Takashi Moriya	748	Massive star mass loss constrained by supernova radio properties
IAUS 371-7		**CH 202**
Susanna Widicus Weaver	2689	The Synergy Between Laboratory Spectroscopy and Observational Astronomy in the Far-IR
Hiroyuki Sasada	2957	Molecular Spectroscopy with optical frequency combs
Stefanie Milam	2799	Laboratory Challenges for Solar System Science
IAUS 373-7		**CH 205**
Manuel Aravena	1357	The supply of gas through cosmic time: insights on the galaxy assembly at early epochs
Kathryn Grasha	385	The Chemical Evolution of Spiral Galaxies from Start of Cosmic Dawn to Today
Ana Carolina Posses Nascimento	1889	Resolving the ISM structure and kinematics in two star forming galaxies at $z \sim 6$
Massissilia Hamadouche	1202	The evolution of quiescent galaxies from $z = 0.6$ to $z = 1.3$

Hannah Stacey	308	How dusty quasars shape the inner regions of galaxies at cosmic noon

IAUS 374-7 **CH 104**

Gonzalo Tancredi	866	What catastrophes of extraterrestrial origin can affect us on various geographical and temporal scales?
Round Table #1		Comparative Analysis of the Astronomical Hazards

FM 3-4 **CH 103**

Jia Liu	2915	Higher-Order Statistics with Stage IV surveys
Matteo Cataneo	623	On the road to percent accuracy: The Reaction Way
Pierre Fleury	820	Cosmic shear from Einstein rings
Sungwook E Hong	561	Weak-lensing Mass Reconstruction of Galaxy Clusters with a Convolutional Neural Network

FM 6-4 **CH 106**

Hiroki Akamatsu	2293	X-ray and radio multi-wavelength view of clusters of galaxies
Junhan Kim	2198	A Multi-Probe Analysis of the 3-D Shapes and Non-Thermal Pressure in the CHEX-MATE Galaxy Clusters
John ZuHone	2972	The interaction between merger-driven gas motions and AGN feedback in clusters of galaxies
Roland Timmerman	1453	Measuring cavity powers of active galactic nuclei in clusters using a hybrid X-ray/radio method
Takuya Akahori	329	Phoenix rising from the ashes - co-existence of violent cooling and AGN feedback
Annalisa Pillepich	2187	X-ray manifestations of AGN feedback, mergers and satellite accretion with the IllustrisTNG simulations

FM 7-4 **CH 109**

François Mignard	879	Status of the Multi-Wavelength Reference Frames
Davide Massari	990	Astrometry with the ELT
Christopher Jacobs	1520	The X/Ka 2022b VLBI Celestial Reference Frame
David Gordon	2709	Current Celestial Reference Frame Status at X/S and K Bands
Aletha De Witt	3100	Imaging and Structure Analysis of ICRF sources at X and K-band
Oleg Titov	3426	New explanation of the observed large positional offsets between radio and optical coordinates of the extragalactic objects

WG 4-3 **CH 108**

Priya Shah	526	Empowering Women through Training and Skill Development
Santiago Vargas Domínguez	1237	How does gender equality benefit men?
Suhyun Shin	559	Challenges for young women astronomers in South Korea to continue their careers based on statistical surveys
Loreany De Araújo	2666	ASTROMINAS: Empowering girls through science
Mayssa El Yazidi	1275	Work opportunities and the study of the female presence in astronomy and space sciences in Tunisia

Lunch Break 12:00-13:30

Afternoon Oral Session 1 13:30-15:00, Convention Hall

Name	Abs. No.	Title

IAUS 370-8 **CH 101**

Ashkbiz Danehkar	387	Time-dependent Numerical Modeling of Thermally Driven Stellar Winds
Varsha Ramachandran	373	Probing the winds and interactions of OB stars in different environments
Darius Modirrousta-Galian	287	Role of Planetary Winds in Planet Evolution and Population
Adam Finley	1470	Rotation of the Solar Corona and Solar Wind Angular Momentum-loss
Pin-Gao Gu	1270	Size Evolution of Close-in Super-Earths through Giant Impacts and Photoevaporation

IAUS 371-8 **CH 202**

Masaomi Tanaka	2499	Heavy element opacity for multi-messenger observations of neutron star mergers
Yu-Jung Chen	2988	VUV Spectroscopy for Photoprocessing of Astrophysical Ices

IAUS 373-8 **CH 205**

Vincenzo Mainieri	1747	The role of AGN outflows and jets in regulating star formation
Kentaro Nagamine	1481	Feedback models in galaxy simulations and probing their impact using cosmological hydrodynamic simulations
Tjitske Starkenburg	2700	The evolutionary path of quenching galaxies and comparisons between theoretical and observational samples

Boris Sindhu Kalita	1996	Direct glimpse at accretion-driven galaxy evolution in the protocluster-era
Kohei Ichikawa	679	Rapidly growing supermassive black holes in extremely radio-loud galaxies
Hao He	856	Analysis of giant molecular cloud properties on FIRE-2 Mergers

IAUS 374-8 **CH 104**

FM 3-5 **CH 103**

Kyle Finner	698	NIRWL: Identifying Systematics in Near-infrared Weak-lensing Measurements with CANDELS/HST
Alessio Spurio Mancini	1574	COSMOPOWER: Deep Learning – accelerated cosmological inference from next-generation surveys
Christopher Hirata	3124	Nancy Grace Roman Space Telescope
Francois Lanusse	2493	Weak Lensing with the Rubin Observatory LSST

FM 6-5 **CH 106**

Rafael Alves Batista	1276	Neutrinos and gamma rays from clusters of galaxies
Saqib Hussain	330	High-energy gamma-ray production in clusters of galaxies
Ji-Hoon Ha	645	Particle acceleration at accretion shocks around galaxy clusters
M. James Jee	1136	Weak-lensing Study of Merging Galaxy Clusters and Probes of Dark Matter
Kyle Finner	696	Weak-lensing analysis of 30 merging clusters that exhibit radio relics
Wonki Lee	1244	Discovery of peculiar double radio relics in the merging cluster ZwCl J1447.2+2619

FM 7-5 **CH 109**

Richard Dodson	2059	Ultra-precise Astrometry with the SKA
David Hobbs	987	The Hidden Regions – Future space astrometry in the Near InfraRed
Yoo Jung Kim	1964	Spectroastrometry with Photonic Lanterns

WG 4-4 **CH 108**

Alshaimaa Saad Hassanin	807	Career challenges, problems, and consequences in the Middle east
Encieh Erfani	458	Iranian Women Astrobomers
Bonita de Swardt	3136	A case study of gender inclusiveness in the Development in Africa with Radio Astronomy (DARA) Big Data programme
Discussion		

Break		15:00-15:15

Afternoon Oral Session 2		15:15-16:45, Convention Hall
Name	Abs. No.	Title
IAUS 370-9		**CH 101**
Sung-Chul Yoon	2556	Effects of rotation on the evolution of early-type stars
Andrew Allan	2472	The Evolution of Atmospheric Escape of Highly Irradiated Gassy Exoplanets
Zsolt Keszthelyi	257	Spin down and reduced mass loss in early-type stars with large-scale magnetic fields
Antoine Strugarek	1423	Architectures of rotating star-planet systems: Comparing theoretical predictions to observations
Gautham Narayana Sabhahit	1480	Mass-loss implementation and temperature evolution of very massive stars
IAUS 371-9		**CH 202**
Jacob Ward	2714	Branching Ratios and Atomic Transition Probabilities of Fe II in the Vacuum Ultraviolet Region
Silvia Spezzano	2945	High Resolution Molecular Spectroscopy in the CAS Laboratories
IAUS 373-9		**CH 205**
Eve Ostriker	1034	Feedback and the Emergence of Star Formation Scaling Relations
Rachel Somerville	2707	Modeling star formation across a vast range of spatial scales
Dandan Xu	932	Linking the rise and fall of star formation with the large-scale angular-momentum environment through circumgalactic medium
Jaeyeon Kim	2070	Environmental dependences of molecular cloud lifecycle in 60 main sequence galaxies
Juan Espejo	919	What drives disk instabilities and star-forming clumps in galaxies at Cosmic Noon?
Chang-Goo Kim	727	How are Galactic Star Formation Rates Regulated? Role of Supernovae, UV Radiation, and Magnetic fields
IAUS 374-9		**CH 104**
FM 3-6		**CH 103**
Hendrik Hildebrandt	2394	Cosmic shear with the ESA/NASA Euclid space mission
Jun Zhang	462	Shear Measurement Strategy in CSST
Discussion		

FM 6-6		**CH 106**
Annalisa Bonafede	2260	Magnetic field in galaxy clusters and beyond: new perspectives from low frequency observations
James Chibueze	277	MeerKAT's view of an interaction between intra-cluster magnetic field and blackhole jets
Erik Osinga	817	The detection of cluster magnetic fields via radio source depolarization
Paola Dominguez Fernandez	306	Substructure and patchiness in radio relics
Jurjen De Jong	968	Particle reacceleration in the pre-merging radio bridge A399-401
Rajsekhar Mohapatra	1174	Multiphase turbulence in the ICM: the role of turbulence heating and the effect of the driving

FM 7-6		**CH 109**
Anna Queiroz	2280	StarHorse parameters for spectroscopic surveys with Gaia EDR3: ages for sub-giants and chemical substructures in the solar vicinity
Chao Liu	3430	When Gaia meets LAMOST
Yuan-Sen Ting	505	Precision Galactic Archaeology: Revealing the Milky Way's Engines through the Statistical Alignment of Stars

WG 5	**CH 108**
John Hearnshaw	The IAU pro-am WG, its mission and future goals
Tim Spuck	Interest in Pro-Amateur Collaboration in Astronomy: What do professionals and amateurs have to say?
Suzana Martins / Lina Canas	Meet the IAU Astronomers! Programme
Aniket Sule	The amateur astronomy culture in India
In-Ok Song / So Weol Lee	Amateur astronomers in Korea
Antonia Varela	The Starlight network and the need for ProAm cooperation for local sustainable development through Astro-tourism
General Discussion	

Break	16:45-17:30

Closing Ceremony	17:30-18:30, Auditorium

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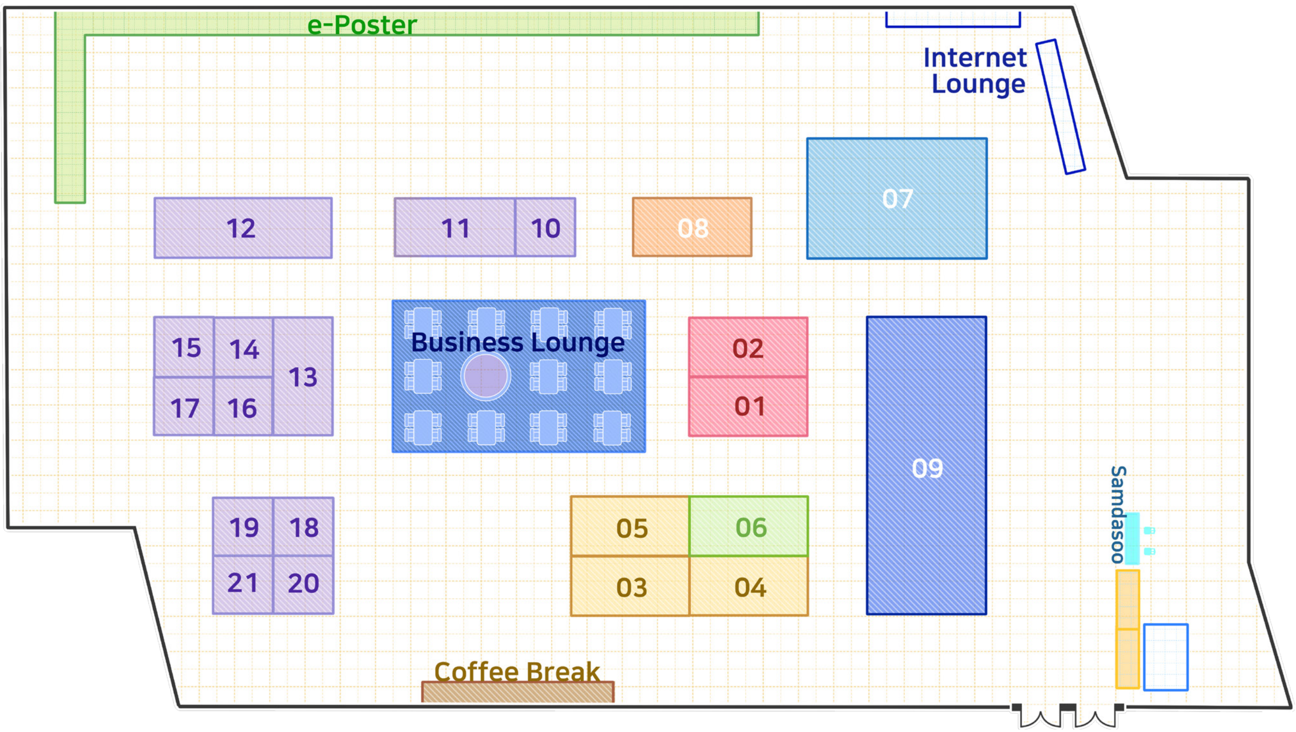

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11	Astralis
12	GA2024 NOC & South African Astronomical Observatory (SAAO) & Southern African Large Telescope (SALT)
13	NSF's NOIRLab
14	Gwacheon National Science Museum
15	International Gravitational Wave Network: LVK (LIGO-Virgo-KAGRA), LISA and NANOGrav
16	SKA Observatory
17	Istituto Nazionale di Astrofisica
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19	UNIST, Center for High Energy Astrophysics
20	Center for the Gravitational-Wave Universe
21	University of Science and Technology

Astronomy for All
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XXXIst General Assembly
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IAUGA 2022

ABSTRACTS

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SYMPOSIUM PLENARY LECTURES

IAUS 368

#1791

Machine Learning in Astronomy: From the Star-Galaxy Separation to a Collaborative Human-AI Discovery

George Djorgovski[1], Matthew Graham[1], Ashish Mahabal[1]

[1]*Astronomy, Caltech, United States of America*

For over 30 years now, Machine Learning (ML) has been used in astronomy, for the ever more complex data handling and analysis tasks. Today, ML is a standard component of the data-intensive astronomy toolkit, with a growing spectrum of applications. These developments are inevitable, driven by the exponential growth of data rates and volumes, the increasing complexity and information content of the data, and the resulting need to automate many data-related tasks. Most of the initial applications were simply outsourcing to ML the repetitive, but not intrinsically very complex tasks, such as the star-galaxy separation in large sky surveys. With the rise of the time domain astronomy (TDA), and the need to process the data, detect and classify potentially interesting transient events, and decide on their follow-up in (near) real-time, the challenges multiplied. ML/AI applications in astronomy now cover many other tasks that are not directly related to sky surveys, including the analysis of numerical simulations, literature searches, planning and execution of observations, etc. Of particular interest are the novel AI methodologies that can discover patterns that humans have missed (or simply cannot recognize due to the inherent complexity), including analytical expressions that describe the data, and not just the geometrical and statistical descriptors. These are the first steps towards a genuine human-AI collaborative discovery.

KEYWORDS Machine Learning, Artificial Intelligence, Data Science, Astroinformatics, Sky surveys, Classification

IAUS 368
#2189

Deep Learning in Astronomy: Trends and Challenges

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Astronomy is undergoing 'industrial revolution', with exponential growth of data sets in both spatial and time domains. We review Machine Learning in Astronomy, from early developments in the 1990s to the present advanced techniques.

The methods are illustrated with applications to current and future galaxy surveys (e.g. DES, DESI, Rubin-LSST and Euclid).

We critically contrast "Deep Learning" with "Shallow Learning" and challenges of explainability and interpretability of the algorithms, in combination with prior human knowledge.

We also discuss training of the next generation of scientists, with the example of UCL's Centre for Doctoral Training in Data Intensive Science.

KEYWORDS Machine Learning, Artificial Intelligence, Deep Learning, Cosmology, Galaxies, Dark Matter, Dark Energy

IAUS 369

#3076

Observational Properties of Fast Radio Bursts

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Fast Radio Bursts (FRBs) are a puzzling cosmic mystery. Consisting of short (few millisecond) bursts of radio waves coming from cosmological distances, FRBs are ubiquitous in the Universe, having an all-sky detection rate of roughly 1000 per day with current telescopes. Yet the origin of FRBs is unknown. Here we review our present knowledge of FRB observational properties including burst characteristics, properties of their host galaxies, and what is known about the FRB population as a whole.

KEYWORDS

IAUS 369

#3077

Multi-wavelength studies and cosmological uses of FRBs

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I will review efforts throughout the community to leverage the enigmatic signals of FRBs and related follow-up, multi-wavelength observations to probe our universe. The applications range from detecting missing baryons, to probing galactic and extragalactic magnetic fields, to studying the density and distribution of gas in galactic halos (including our own), to constraining the expansion rate of our universe. I will summarize recent results in these areas, highlighting advances and continued uncertainties, and then discuss the exciting prospects for rapid progress due to next-generation FRB surveys.

KEYWORDS

IAUS 372

#2818

Challenges and opportunities in solar and heliospheric physics at the dawn of the multi-messenger era

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In the 90s, the Ulysses mission's resulst substantiated the heliosphere as a multi-messenger paradigm. In this decade, the start of operations of the NSF's Daniel K Inouye Solar Telescope (DKIST) coincides with the science phases of two solar encounter missions, Parker Solar Probe (NASA) and Solar Orbiter (ESA/NASA). The three facilities constitute a multi-messenger suite destined to help us understand how the heliosphere is magnetically connected back to the Sun. By getting closer to the Sun, the two spacecraft can measure in-situ the pristine consequences of the processes observed at the solar surface with unprecedented detail and sensitivity using DKIST. The ability to detect spectropolarimetric signals from the Solar Corona is a novel and unique capability that DKIST will contribute to this effort. In this talk, I will outline some multi-messenger science cases that will benefit from combining the three facilities using different vantage configurations created by their orbits around the Sun.

KEYWORDS Sun, Heliosphere, DKIST, Solar Orbiter, Parker Solar Probe, multi-messenger

IAUS 370

#2488

Winds and magnetospheres from stars and planets: similarities and differences

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Both stars and planets can lose mass through an expansive wind outflow, often constrained or channelled by magnetic fields that form a surrounding magnetosphere. The very strong winds of massive stars are understood to be driven by line-scattering of the star's radiative momentum, while in the sun and even lower-mass stars a much weaker mass loss arises from the thermal expansion of a mechanically heated corona. In exoplanets around such low-mass stars the radiative heating and wind interaction can lead to thermal expansion or mechanical ablation of their atmospheres. Stellar magnetospheres result from the internal trapping of the wind outflow, while planetary magnetospheres are typically shaped by the external impact from the star's wind. But in both cases the stressing can drive magnetic reconnection that results in observable signatures such as X-ray flares and radio outbursts. This talk will aim to give an overview of the underlying physics of these processes with emphasis on their similarities and distinctions for stars vs. planets.

KEYWORDS stars, planets, winds, magnetospheres, magnetic reconnection

IAUS 371
#1721

Turning Chaos into Order: The Life and Work of Charlotte Moore Sitterly

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At the 1988 IAU in Baltimore, among many who offered reminiscences of earlier meetings, was Charlotte Moore Sitterly. She first attended the 1932 meeting, in Cambridge, Mass, though she already "helped to assemble material for delegates" since the 1920s, for astronomers at Princeton, Mount Wilson and the Lick Observatory. She was an ardent member of the new Commission 14 (then called "Fundamental Spectroscopic Data") eventually becoming its president. In her 1988 reminisce, she remembered that the Commission meeting was sparsely attended and very informal but astronomers' "never ending demand for tables and data analysis" soon changed all that. Here we provide a brief overview of how Charlotte Moore Sitterly came to be at the very center of that change, which Donald Menzel early on described as having "turned chaos into order" and just a "little short of miraculous." We will recount her early life, aspirations, training and contributions during her years at Princeton, Berkeley, Mount Wilson and the National Bureau of Standards.

KEYWORDS sitterly, moore, spectra, multiplet

IAUS 371

#1234

Legacy of Charlotte Moore Sitterly in the Internet Age

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Most (yet not all) results of CMS's atomic physics research, which was closely connected to astrophysics, are now incorporated in online databases, one of which is the Atomic Spectra Database of the National Institute of Standards and Technology. The use of this database extends far beyond astrophysics, but I will focus on astrophysical applications. I will discuss the impact of CMS's work on modern atomic physics and outline problems that urgently need solutions.

KEYWORDS Moore, AEL, atomic data, energy levels, multiplets, spectral lines, online databases

IAUS 373
#3017

Star Forming Galaxies Resolved into their Fundamental Units

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Especially powered by ALMA, HST, optical IFU, and soon JWST, the last decade has seen an explosion in highly resolved studies of nearby galaxies. These new observations, both from big surveys and groundbreaking dedicated surveys targeting individual galaxies, break individual galaxies into discrete HII regions, molecular clouds, dust clouds, and star clusters. Achieving such a view across a diverse sample of galaxies has has unveiled the coupling between molecular clouds and their host galaxies, the life cycle of individual star forming regions, and the links between gas density, molecular cloud properties, and star formation activity. I will give an overview of these observationally-driven advances, summarizing our new paradigm for star-forming molecular clouds in galaxies, in which clouds live dynamic lives and show close coupling to their parent galaxies. Though most observations support an important role for the host galaxy and rapid feedback, major questions still remain and I will highlight some of these major open questions, describing the next round of likely advances that we can expect from JWST, ALMA, and major new surveys by the VLA, the SKA precursors, and the next generation of SDSS.

KEYWORDS Star formation, Galaxies, Interstellar Medium

IAUS 373

#2165

Star formation across the bodies of galaxies and its suppression: a theoretical overview

Annalisa Pillepich[1]

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I will review the current general understanding of how star-formation, and its suppression, proceeds according to numerical cosmological hydrodynamical simulations of galaxy formation and evolution. We will go on a journey as a function of cosmic epochs and across galaxy masses and types; I will highlight the differences between central or field galaxies and satellites, and will show how the fate of the latter depend on the properties of their group or cluster hosts. I will then provide arguments for the physical processes that can bring star formation to a halt, including and contrasting AGN feedback and environmental mechanisms, and how all these unfold within the galaxies' bodies.

KEYWORDS

IAUS 373
#634

Exploring star formation and quenching via observations, simulations and synergies

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Via multi-wavelength synergy surveys, the galaxy population has been studied in increasing detail across multiple scales and from local to high redshifts, including their stellar mass, star formation level, multi-phase gas content, morphology, structure and kinematics, metallicity, environment, feedback process, and more. I will try to discuss key interrelationships among these galaxy properties, and explore galaxy assembly in four key aspects: star formation, quenching, stellar mass function evolution and galaxy-halo connection. I will show new evidence from multi-wavelength observations from optical to radio that demonstrate how star formation and quenching operate in galaxies and the implied physical mechanisms. These new observational results are compared to model predictions and different hydro-dynamical simulations. I will discuss the great successes and failures of simulations in reproducing key observations, which in return put new constraints on physics, in particular the AGN feedback model. At last, I will discuss recent progress in investigations on the galaxy-halo connection and evolution.

KEYWORDS Galaxy evolution, star formation, quenching, simulations

IAUS 374
#3453

Rare Earth Got It Wrong: Astronomical Hazards and Habitability

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Astronomical hazards for life (including intelligent life) have comprised a large segment of the arguments invoked in favor of the "Rare Earth" hypothesis in astrobiology. There are several independent recent developments, however, suggesting that these hazards, while immensely destructive in local terms, are unlikely to severely depress habitability over large parts of the Galactic Habitable Zone, especially in late epoch of the Galactic evolution. These developments are reviewed here, and some directions for further works are outline, in particular in domains of large-scale numerical simulations of habitability and analysis of the relevant observation selection effects and biases. As in many other fields of study – and human life in general! – what is originally seen as a threat, often hides some unexpected opportunities.

KEYWORDS habitability, rare Earth hypothesis, selection effects and biases, counterfactuals, numerical simulations in astrobiology

IAUS 368

Machine Learning in Astronomy: Possibilities and Pitfalls

Invited & Contributed Talks

IAUS 368

#3253

Tutorial for the broader community

Sara Webb[1]

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In this workshop session I'll give a brief overview of what machine learning is and delve into the many different types of learning algorithms and how to evaluate which are best for whatever your problem at hand is. Machine learning has opened a world of possibilities for us astronomers working with large amounts of data, however if not careful, users can trip into common pitfalls. I will focus on solving problems related to time-series light curve data and optical imaging data mainly from the Deeper, Wider, Faster Program (DWF). The workshop will provide hands on Jupyter notebooks and data to demonstrate these different techniques and help you build a small toolkit to take back with you for use on your own future machine learning projects.

KEYWORDS

IAUS 368

#3009

Classic Machine Learning vs Deep Learning: when, why and how?

Guillermo Cabrera-Vives[1]

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Over the past decade, Deep Learning (DL) has proven to outperform classical Machine Learning (ML) methods in solving challenging problems. This has led astronomers to start applying many DL techniques to different problems, such as galaxy morphological classification, transient discovery, and light curve classification, among others. One of the challenges in applying the newer DL architectures is that the number of parameters to be optimized is huge, causing models to overfit unless you have a massive enough data set to train them. One solution is to perform strong regularization, but by doing so, is it possible to overcome classical ML models such as a support vector machine or a random forest? The question arises: when should I use a DL model instead of a classic ML model? We will address this question using an example based on ZTF light curve classification as done by the ALeRCE brokering system.

KEYWORDS

IAUS 368
#2178

ERGO-ML: Extracting Reality from Galaxy Observables with Machine Learning

Annalisa Pillepich[1]

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Current cosmological (magneto)hydrodynamical galaxy simulations, such as IllustrisTNG (https://www.tng-project.org/), are producing increasingly larger samples of simulated galaxies (> tens of thousands) of increasing realism and detail. They are hence sufficiently mature and large in scope that can be combined with machine learning techniques for a variety of applications. Here I will discuss our project ERGO-ML where we aim at Extracting Reality from Galaxy Observables with Machine Learning, across a wide range of physical properties of galaxies and utilizing diverse sets of observations, e.g. from photometry to spatially-resolved spectroscopy, from stellar light to gaseous signatures, from the innermost regions of galaxies to their dim stellar and gaseous haloes, from scalar features to maps and multi-dimensional data cubes. We use and combine state-of-the-art cosmological simulations of galaxies and forward-modeling into observational space to develop methods for direct application to observational data in order to "train on simulations and apply to observations". For example, we have already shown that it is possible to retrieve e.g. the time and the mass of the last major merger that a galaxy has experienced from a handful of integral galaxy properties that are commonly available from large photometric galaxy surveys, such as its total galaxy stellar mass, stellar morphology and average stellar age (Eisert, Pillepich+ 2022). To do so we have trained Multilayer Perceptron Neural Networks and Conditional Invertible Neural Networks (cINNs) on the IllustrisTNG outputs and merger histories and shown that, via simulation-based inference, we can in principle recuperate the unobservable past history of observed galaxies. By utilizing the cINNs, we have been able to infer not only the point predictions, but the full posterior distributions for the predicted parameters and to hence estimate the uncertainties in the predictions. Among other ERGO-ML directions, we are now extending this proof of concept to the spatially-resolved maps of galaxies that mock observations with the Hyper Suprime-Cam Subaru Strategic Program, to infer the past merger and assembly history of observed galaxies from their stellar-light maps.

KEYWORDS

IAUS 368

#1545

Machine Learning in Astronomy

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The next generation of telescopes such as the SKA and the Vera C. Rubin Observatory will produce enormous data sets, far too large for traditional analysis techniques. Machine learning has proven invaluable in handling massive data volumes and automating many tasks traditionally done by human scientists. In this talk, I will give a review of machine learning in astronomy, highlighting the impact and challenges of applying machine learning techniques to astronomical data. I will also discuss recent developments in unsupervised learning, focusing on scientific discovery through anomaly detection.

KEYWORDS machine learning

IAUS 368
#1870

Existing data sets for machine learning in Astronomy

Renee Hlozek[1]

[1]Astronomy and Astrophysics, University of Toronto, Canada

Machine learning in astronomy is growing from strength to strength, with many new approaches and techniques being developed to address some of the upcoming challenges of large surveys. In this review talk, I will describe some of the astronomical data sets and simulations being used to prepare for the coming data deluge and the challenges in creating data sets to test machine learnning methods, and testing machine learning performance.

KEYWORDS machine learning, astronomy, simulation, challenge

Detecting complex sources in large surveys using an apparent complexity measure

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[1]*Theoretical Astrophysics, KASI, Republic of Korea*
[2]*School of Mathematics and Physics, University of Queensland, Australia*

Large area surveys in the optical, IR and radio will generate very large datasets, and these will almost certainly contain new objects of a type that has never been seen before. The detection of 'unknown unknowns' by an algorithm is a difficult problem to solve, as the most unusual things are often easier for a human to spot than a machine. In this work we use the concept of apparent complexity, previously applied to detect multi-component radio sources, and use it to scan the radio continuum Evolutionary Map of the Universe (EMU) Pilot Survey data for complex and interesting objects. This method is very quick, and generalises well from our training sample (ATLAS) to the EMU pilot survey data. The complexity approach allows us to scan the survey image for such interesting objects in a fully automated and blind manner. In this talk I will define how the complexity is defined and measured, how we applied it to the Pilot Survey data, and how we calibrated the completeness and purity of these interesting objects using a crowd-sourced 'zoo'. The results are also compared to unexpected and unusual sources already detected in the EMU Pilot Survey, including Odd Radio Circles, that were found by human inspection.

KEYWORDS machine learning, radio continuum

IAUS 368
#2021

In Search of the Peculiar: An Unsupervised Approach to Anomaly Detection in the Transient Universe

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[2]*High Energy Astrophysics, Harvard & Smithsonian Centre for Astrophysics, United States of America*

The era of big data time-domain Astronomy is here, and with planned projects such as the Vera-Rubin Telescope, the scale of the data available is escalating at an astonishing pace. Perhaps, the most scientifically promising aspect of these surveys is their potential for discovery across the transient universe. Yet, current methods are restricting this potential due to their inability to handle databases of extreme size and multidimensional nature. Currently, rapid analysis to systematically identify scientifically compelling objects in time for relevant spectroscopic follow up is near impossible. We present an approach that tackles the challenges presented by the onslaught of data to identify the most anomalous light curves in current and future time-domain surveys. We deploy an Unsupervised Random Forest method using a combination of normalized light curve points and their spectral power spectrum as features, using observations from the first two years of TESS, to systematically identify anomalous objects. Our method identifies a wide range of variability patterns and successfully identifies several documented scientifically compelling targets discovered by the community to date. This approach complements the TESS Objects of Interest (TOI's) list by expanding the discoveries beyond the primary mission focus. We increase the census of rare variable classes, such as pulsating stars and eclipsing binaries, by publishing our list of anomaly scores along with notes from a systematic inspection of over 10,000 anomalies, many of which are previously unidentified. We combine our results with Gaia photometry to establish a relation between our Weirdness metric and the evolutionary stage of anomalies, revealing candidates within the instability strip, young stellar objects, white dwarf stars and many others. Furthermore, we discover a link between the anomaly score and physical properties, such as the orbital parameters of eclipsing binaries.

KEYWORDS surveys, methods: analytical, methods: statistical, stars: peculiar, Hertzsprung-Russell diagram

IAUS 368

#1003

Unsupervised classification: a necessary step for Deep Learning?

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[3]Laboratoire J.A. Dieudonné, Université Côte d'Azur, France
[4]IPAG, Université Grenobe-Alpes, France

In a data-intensive era, turning to automated statistical methods has become essential in most scientific fields, including astronomy and astrophysics. Such methods make possible the analysis of large quantities of data of various forms, ranging from images to spectra, time series, and much more. They are capable of tackling lots of challenging tasks: inference problems, clustering, pattern recognition, and so on.

Deep-learning algorithms have gained a lot of popularity in the past few years. However, their supervised nature makes them fully dependent on the quality and completeness of the data samples used in the training processes. And when it comes to galaxy spectra for instance, there is simply no suited training sample available yet. This is where unsupervised classification (clustering) can come to the rescue.

Using the discriminant latent mixture-model based algorithm Fisher-EM, we managed to classify circa 700 000 spectra of galaxies from the SDSS (Fraix-Burnet et al. 2021) and we are extending this study to higher redshifts thanks to the VIPERS data (circa 80 000 spectra). We have investigated the discriminative capacity of the method and its robustness with respect to noise on a sample of galaxy spectra simulated with the code CIGALE. We are in the process of providing a full physical description of the classes of spectra with the help of the galaxy SED modeling code PEGASE.

Our results can be used in several ways. Firstly, we provide a data-driven atlas of galaxy spectra with its evolution in redshift. Secondly, the statistical mixture-based model can be used to instanteneously classify any new spectra by simply computing the probabilities for this spectra among all the classes. Lastly, we are building a data-driven training sample of nearly 800 000 optical spectra of galaxies up to a redshift of 1.2 that can be used for instance in Deep Learning approaches.

KEYWORDS Clustering, Unsupervised, Spectra, Galaxies

IAUS 368

#1049

Iterative Grid Refinement: Approximate Gaussian Processes for Billions of Parameters

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Gaussian Processes are highly expressive models used for their uncertainty estimates and interpretability. A major limitation is their computational complexity. Naively, Gaussian processes scale with $O(N^3)$ where N denotes the number of parameters. This significantly hampers their applicability for imaging in the domain of astrophysics with millions or even billions of degrees of freedom. Current approaches to overcome this limitation either rely on inducing points and do not solve the cubic scaling at its core, require sparse covariance matrices, or represent the Gaussian process on a regular grid and do not generalize to e.g. spherical or polar coordinates. Here, we aim to represent Gaussian processes on irregular grids in O(N) time with only loose constraints on the kernel. We devise an algorithm to model Gaussian processes on a user-specified, potentially irregular grid using an iterative approach. Within this scheme we are able to represent long- as well as short-range correlations by combining views of the grid at varying resolutions. Our approximative algorithm efficiently applies steeply falling kernels in O(N) time. The model is especially efficient for rotationally or translationally symmetric irregular grids like polar or spherical coordinates. We showcase such an efficient implementation for the voxelization of the Milky way in 3D for the reconstruction of interstellar dust with 122 Billion degrees of freedom.

KEYWORDS Gaussian Processes, Machine Learning, Big Data, Kernel Methods, Bayesian Modeling, Interstellar Medium

IAUS 368
#1830

Unraveling the physical mechanisms of pulsating stars through a multimodal and multidisciplinary machine learning approach

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[1]*Institute of Astronomy, KU Leuven, Belgium*

Space missions such as Kepler and TESS and large ground-based surveys such as SDSS and LAMOST are providing the astronomical community with massive amounts of photometric and spectroscopic observations of millions of stars. Gaining insights into the physical mechanisms governing these stars benefits from the creation of a machine learning framework that combines the photometric and spectroscopic observations. We therefore couple our supervised stellar variability machine learning classifier based on light curve data with an unsupervised learning algorithm that relies on descriptive tools from the biomedical domain and with spectroscopic information from ground-based telescopes. By combining this variety of machine learning algorithms into one framework, we go beyond the mere variability classification of stars. Rather than focusing only on discovering the stars of interest, this new methodology allows us to move towards a knowledge-discovery driven approach that has the potential to provide new insights into the physics governing these stars, with applications foreseen to pulsating stars. In particular, we use our new methodology to hunt for the physical interplay between rotation and multiperiodic pulsations for single and binary stars.

KEYWORDS TESS, Kepler, machine learning, light curves, spectroscopy, asteroseismology

IAUS 368
#984

Time-domain photometry and machine learning with OGLE and Gaia

Lukasz Wyrzykowski[1]

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Machine learning is a great tool for astronomy and has been successfully employed in multiple astronomical topics. However, time-domain photometry poses an additional layer of complexity with the data spanning in an additional but irregular dimension, the time. I will describe some of the early attempts at using Machine Learning tools in time-domain photometry astronomical problems, including OGLE eclipsing binaries and microlensing events and Gaia alerts.

KEYWORDS Gaia, OGLE, time-domain, machine learning

IAUS 368
#1546

Enhancing Exoplanet Surveys via Physics-informed Machine Learning

Eric Ford[1]

[1]Astronomy & Astrophysics, Penn State, United States of America

The discovery and characterization of potentially Earth-like planets around Sun-like stars is a long-term goal for exoplanet surveys. While the Doppler technique for detecting exoplanets is making progress towards this goal, one key remaining question is "How can astronomers separate true Doppler shifts from spurious signals due to intrinsic stellar variability?". This talk will provide an overview of the challenges and recent progress in mitigating stellar variability using machine learning methods. Of particular interest is how astronomers are working to integrate their extensive domain knowledge of stellar physics, telluric absorption, instrumental behavior with machine learning algorithms, so as to achieve greater sensitivity than is possible with either approach alone. Next, the talk will consider the challenges of validating such methods and adapting models to stars for which validation is not possible.

KEYWORDS astrostatistics, physics-informed machine learning, exoplanets, spectroscopy, time series, stellar variability, sun-as-a-star

IAUS 368
#927

A review of current tools for outreach & education

O. Ivy Wong[1]

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I will present a review on some of the current tools and libraries available to astronomers for the purposes of outreach and education. In an era when information on any topic can be found with a few swipes of one's finger a glass screen, an astronomer's toolkit for outreach and education has expanded beyond star charts, work sheets and wrangling an unwieldy Dobsonian into position. In the past 10 to 15 years, we have observed an increase in excellent online astronomy education and outreach tools (and libraries) that span across a wide range of topics in astronomy and astrophysics. There are also educational material that target children in different age groups, in addition to tools available in multiple languages to enhance accessibility to non-English speaking demographics. I will highlight a few of these in this review. As the intent of this symposium is to promote best practices for leveraging machine learning in astronomy research, I also hope to demonstrate that citizen science is a multipurpose data-driven tool that can be employed for education and outreach, in addition to generating high quality training data for future machine learning developments.

KEYWORDS

IAUS 368

#1744

Simulating Transient Noise Bursts in LIGO with Generative Adversarial Networks

Melissa Lopez[1], Vincet Boudart[2], Amit Reza[3], Sarah Caudill[3]

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[3] *Institute for Gravitational and Subatomic Physics, Utrecht University, Netherlands*

The noise of gravitational-wave (GW) interferometers limits their sensitivity and impacts the data quality, hindering the detection of GW signals from astrophysical sources. For transient searches, the most problematic are transient noise artifacts, known as glitches, that happen at a rate around $ 1 \text{ min}^{-1}$, and can mimic GW signals. Because of this, there is a need for better modeling and inclusion of glitches in large-scale studies, such as stress testing the pipelines. In this proof-of concept work we employ Generative Adversarial Networks (GAN), a state-of-the-art Deep Learning algorithm inspired by Game Theory, to learn the underlying distribution of blip glitches and to generate artificial populations. We reconstruct the glitch in the time-domain, providing a smooth input that the GAN can learn. With this methodology, we can create distributions of $\sim 10^{3}$ glitches from Hanford and Livingston detectors in less than one second. Furthermore, we employ several metrics to measure the performance of our methodology and the quality of its generations. This investigation will be extended in the future to different glitch classes with the final goal of creating an open-source interface for mock data generation.

KEYWORDS gravitational waves, detector characterisation, machine learning, synthetic data

IAUS 368
#1150

Galaxy Zoo: Practical Methods for Large-Scale Learning

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[2]*Physics and Astronomy, University of Oxford, United Kingdom*

Deep learning is fundamental to creating Galaxy Zoo's latest catalogs. In this talk, we explore the methods we've developed to best exploit large-scale human labels and how other researchers can benefit from them.

We open by presenting Galaxy Zoo LegS - new deep-learning-powered detailed morphology measurements for 8 million galaxies imaged by the DESI Legacy Surveys. Our models are trained on human labels collected over 8 years, during which time different volunteers answered different questions and followed different instructions. We describe how we overcome the resulting label distribution shift to learn from more human responses than any previous astronomical model.

We next show how simultaneously answering every Galaxy Zoo question forces the resulting models to learn meaningful semantic representations of galaxies. These representations can then be directly used for similarity search and to outperform a recent approach at personalized anomaly-finding. Further, and crucially for other researchers, because the models are trained on a diversity of tasks (answering every GZ question), the trained models make excellent base models to finetune to new tasks. We demonstrate this by finetuning to find ringed galaxies. Models pretrained on all GZ questions are better able to find rings than models pretrained on a single GZ question or on ImageNet. We go on to exploit this to create the largest ringed galaxy catalog to date by an order of magnitude. Our trained models are available for the community to finetune for their own tasks at www.github.com/mwalmsley/zoobot (in both TensorFlow and PyTorch) .

Finally, we describe our very latest work combining self-supervised approaches with broad supervised pre-training on Galaxy Zoo to classify galaxies better than with either alone. We believe such approaches are ideally suited to Euclid and Rubin because they allow us to leverage both the millions of human labels collected over the last decade and the raw scale of unlabelled images these new surveys will produce.

KEYWORDS deep learning, galaxies, survey, statistics, software, analysis, citizen science

IAUS 368
#707

Incorporating Errors in Machine Learning Methods

Joshua Speagle[1]

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Many machine learning (ML) methods are designed to both train over and predict point estimates. In other words, these methods do not incorporate any knowledge of errors -- both known or unknown -- into the inputs or the outputs (or even in the parameters that determine the ML architecture). I will first provide a general overview of what effect this has on both training and predictions, and in what regimes we might need to worry about them. Building on this, I will highlight a few empirical approaches in the literature that try to tackle this and under what types of assumptions they are valid. I will then describe more exact approaches to incorporate measurement uncertainties into ML methods, along with some tractable approximations. I will close by highlighting several astronomical examples where these more exact approaches have been applied.

KEYWORDS machine learning, errors

IAUS 368
#2501

Comparing machine learning and deep learning models to estimate quasar photometric redshifts

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In this work we evaluate machine learning models for predicting photometric redshifts of quasars, astronomical objects that are among the most distant ones in the Universe. We have trained classical machine learning models (Random Forest and k-Nearest Neighbors) and, based on Lima et al. (2022), a deep learning model (Bayesian Mixture Density Network). For that, we use photometric data from the Southern Photometric Local Universe Survey (S-PLUS), Wide-Infrared Sky Survey (WISE) and Galaxy Evolution Explorer (GALEX). The S-PLUS is a large-sky survey with 5 Sloan-like broad bands and 7 unique narrow bands centered in some main stellar features. Our quasar sample contains about 27 thousand spectroscopically confirmed by Sloan Digital Sky Survey (SDSS). By performing a 5-fold cross-validation with a stratified split of our sample, we were able to compare multiple models built with different combinations of features in magnitudes, colors and/or ratios. In summary, our best classical ML model was a Random Forest with normalized median absolute deviation (NMAD) of 0.098, root mean square error (RMSE) of 0.434 and bias of 0.0005, considering all magnitudes in the feature space, including the narrow bands. The best Bayesian Mixture Density Network model was also trained with all magnitudes, and has NMAD of 0.069, RMSE of 0.512 and bias of -0.256. Although both models have comparable results and provide similar single-point estimates, the deep learning model has the advantage of providing probability distribution functions (PDFs) for the photo-zs. PDFs as model outputs can show very relevant information: as obtained by running FlexCoDE (Izbicki & Lee, 2017) via random forests, we see that including the S-PLUS narrow-band magnitudes in the feature space results in less dispersed PDFs. Finally, when it comes to quasars, dealing with limited sample sizes is a challenge, especially at high redshifts. Accordingly, with the purpose of improving performance at the extremes of the spectroscopic redshift distribution, we have tested artificial increase of data with resampling techniques (such as XDGMM, Bovy et al. 2011) that have shown positive results.

KEYWORDS quasars, photometric redshifts, machine learning, deep learning

Searching for the extra-tidal stars of Galactic globular clusters with high-dimensional clustering analysis

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Three-body interactions can eject stars from the core of a globular cluster, causing them to enter the Galactic halo as extra-tidal stars. While finding extra-tidal stars is imperative for understanding both star cluster and Galaxy evolution, connecting isolated extra-tidal field stars back to their birth cluster is extremely difficult. In this work, I will present a new methodology for identifying extra-tidal stars of any Galactic globular cluster using high-dimensional data analysis and a particle spray code. Specifically, this talk will focus on how unsupervised machine learning clustering algorithms like t-SNE and UMAP are successful tools for associating escaped stars with their birth clusters. Furthermore, I will explain how these methods can be extended to identify not just single stars, but entire stellar populations throughout the Milky Way via chemical and kinematic similarities. Ultimately, this talk will highlight the practicality of applying high-dimensional analysis to large populations as data collection capabilities of astronomical surveys continue to increase in the coming years.

KEYWORDS stars, star clusters, globular clusters, clustering algorithms, high-dimensional data analysis, chemical abundances, stellar kinematics

IAUS 368

#515

Accelerating astronomy workflow with deep learning and interpretable A.I

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As we cruise through the age of information, we face a steep rise in data availability, especially high-resolution data in astrophysics. Extracting physics from such large datasets is computationally intensive and conditional on assumed physical models. Hence, such large data is ideally suited to be used with Deep Learning (DL) methods for applications ranging from forecasting to classification to inversion. We present two examples of deep learning massively accelerating workflow in the domain of heliophysics and spaceweather. First, we present the application of a GoogLeNet-Long Short Term Memory cell (LSTM) based solar wind forecasting model, given solar coronal full disc image data. This work shows the potential of exploiting such large datasets to generate space weather predictions. Furthermore, in this work, we show that such a DL model (WindNet) may be probed by feature activation methods to understand what aspects of the input are important for WindNet to generate a particular forecast. From such an analysis, we find WindNet deems coronal holes important 3-4 days before forecasting the fast solar wind – something known well through physics and not explicitly given to our model. Similarly, it deems both Active regions and Coronal holes important for the slow wind prediction, though the timing is missed. Next, we present an application of incorporating known physics into deep learning to perform forecasts of geomagnetic perturbations given changing conditions in the solar wind. Incorporating known physics lets us perform forecasts at high spatial and temporal cadence in the order of seconds. Such models are imperative for accurate and timely spaceweather forecasting, especially in the era of space exploration. Finally, we discuss potential applications and caveats in using DL techniques for inferring physics hitherto unknown while also discussing how DL potentially eases multiple aspects of heliophysics workflows - especially through open-source workflows.

KEYWORDS deep learning, solar wind, spaceweather, solar physics, magnetosphere, geomagnetism, interpretable AI

IAUS 368
#503

Quantifying non-Gaussianity with mathematical insights from machine learning

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A critical bottleneck in cosmology is how to capture non-Gaussianity, and we have thus far relied on higher-order moments. However, higher-order moments often suffers from noisy estimations. I will discuss how mathematical insights from the convolutional neural networks have led to more robust analytic tools to capture high-order moments sans deep learning. I will demonstrate that capturing higher-order moments information with only sublinear operations is possible. Our work, which is based on a technique known as scattering transform, outperforms other higher-order statistics in weak lensing and 21-cm reionization. If time permits, I will also discuss how a machine learning generative approach allows us to capture the likelihood of the system without summary statistics.

KEYWORDS Machine Learning, Cosmology, Large-Scale Structure, Reionization, Statistics

e-Posters

IAUS 368

#3384

Deep Learning Classification of Noise Transients using Multi-Scale Neural Networks applied to LIGO's Auxiliary Channel Data

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We demonstrate that a deep learning classifier that only uses to gravitational wave (GW) detectors auxiliary channel data can distinguish various types of non-Gaussian noise transients (glitches) with significant accuracy, i.e., ~80%. The classifier is implemented using the multi-scale neural networks (MSNN) with PyTorch. The glitches appearing in the GW strain data have been one of the main obstacles that degrade the sensitivity of the gravitational detectors, consequently hindering the detection and parameterization of the GW signals. Numerous efforts have been devoted to tracking down their origins and to mitigating them. However, there remain many glitches of which origins are not unveiled. We apply the MSNN classifier to the auxiliary channel data corresponding to publicly available GravitySpy glitch samples of LIGO O1 run without using GW strain data. Investigation of the auxiliary channel data of the segments that coincide to the glitches in the GW strain channel is particularly useful for finding the noise sources, because they record physical and environmental conditions and the status of each part of the detector. By only using the auxiliary channel data, this classifier can provide us with the independent view on the data quality and potentially gives us hints to the origins of the glitches, when using the explainable AI technique such as Layer-wise Relevance Propagation (LRP) or GradCAM.

KEYWORDS Gravitational Wave, Deep Learning, Multi-scale Neural Networks, LIGO, Glitch, Classification

IAUS 368

#3307

Development of an image similarity retrieval engine using Convolutional Neural Network for automating galaxy morphology classification

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We present the construction of an image similarity retrieval engine for the morphological classification of galaxies using a convolutional neural network (CNN). We adopted the Autoencoder model in the CNN which allows compression and extraction of galaxy image features. As a basic data set, we utilized 106,285 galaxies in the Galaxy Zoo 2 (GZ2) data set in which their morphologies are classified by visual inspection. The Sloan Digital Sky Survey (SDSS) DR12 g, r, & i band images of these galaxies are also used for the training of the model. We set the training batch size to 42, and for each batch, we selected the data so that the morphologies of the galaxies are not biased toward a specific one. Finally, 2150 epoch learning was performed. By comparing output images returned from the constructed model with original input images, we found that the two images are visually similar with a mean residual of 0.005, implying that the image features are efficiently compressed through the encoder of our model. We also investigate the accuracy of the morphological classification of galaxies. We constructed a database of galaxy image features of 124,777 galaxies with available morphology from the three galaxy catalogs of GZ2, EFIGI (Extraction de Formes Idéalisées de Galaxies en Imagerie), and Nair et al., by applying the encoder of our model About 10% of galaxies were randomly selected as a verification sample, and a galaxy with image features similar to each galaxy in the verification sample was retrieved from the remaining 90% of the database. The accuracy of morphology classification was examined by comparing the morphology of the verification sample with that of the retrieved one; the correlation coefficients of the morphology between the two samples are 0.61, 0.82, and 0.75 for GZ2, EFIGI, and Nair et al. catalogs, respectively. We propose that our machine learning technique can classify galaxy morphology very efficiently, similar to that performed by humans.

KEYWORDS Convolutional Neural Network, Autoencoder, similarity retrieval engine, morphology, galaxies

IAUS 368

#3306

Image Restoration based on Deep Learning for High-Resolution Solar Images

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The Earth's turbulent atmosphere is an obstacle to obtain high-resolution solar images with a ground-based telescope. AO is commonly used although it is difficult to remove seeing-induced wavefront errors over wide FoV. Another method is to apply post-processing image restoration such as Multi-Frame Blind Deconvolution (MFBD) by using many images obtained in a short time. However, it requires a huge computational cost and is not possible to analyze the images in real-time. Asensio Ramos et al. (2018) proposed the way using a deep learning to overcome this problem. They conducted supervised learning using images of photospheres and chromospheres restored by MFBD as a target data of the neural network. However, there are still problems in terms of selection of the target images and evaluation of output images. In order to use the image restoration based on the neural network in a real observation, it is necessary to demonstrate reliability that the output images represent the true images. To overcome the difficulties, we study an image restoration method based on the neural network but using images of photospheres calculated by the MURaM MHD simulation as target images for the supervised learning. We use U-net (Ronneberger et al., 2015) that is a high performance neural network in the field of image processing. The seeing degraded images are obtained by applying PSFs based on a Kolmogorov phase screen, which are used as input images. For the degraded images, a low-order wavefront errors were corrected before inputting to the neural network to simulate AO in an actual observation. We test the neural network and study the quality of the output images using four evaluation indexes: correlation coefficient, contrast, RMSE, and SSIM. By evaluating the indexes and visual comparison between the output and correct images, we find that the quality of images has been improved by the neural network and there are no obvious artificial structures in the output images.

KEYWORDS high angular resolution, image processing

IAUS 368
#3283

Machine Learning for Hazardous Small Solar System Body Detection

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The observational uncertainties of small bodies, combined with the chaotic nature of the solar system, makes predicting collisions an inherently difficult task as small deviations in the initial phase space parameters can lead to extraordinary variations in final positions. Conventionally, using a Monte-Carlo approach, the impact probability of an object is quantized by launching virtual objects with orbital parameters that are statistically sampled from within their respective error ellipse. The impact probability is subsequently determined based on the fraction of virtual asteroids that reach Earth within some predetermined striking distance. The accuracy of this approach depends on the magnitude of the observational uncertainties and the number of virtual objects used in the simulations. To sufficiently cover all outcomes, the required amount of virtual objects can become computationally intractable for objects with short data arcs and/or close encounters with large bodies.

Using virtual examples of objects that are guaranteed to collide with Earth, which are generated by launching objects from future positions of Earth's surface and integrating backwards in time, a machine learning network can be trained to identify hazardous objects based off of their orbital topologies. Because this form of estimation does not depend on a phase-space position at a particular moment in time, the network is more resilient to perturbations of initial conditions, i.e. chaotic motion. Building off of our previous work (Hefele, et al. A&A, 634 (2020) A45), in addition to estimating the chance of impact, we aim to create a network which also predicts the time of impact. Additionally, to validate the results of the machine learning algorithm, we explore inferring the future positions of solar system objects using physically informed neural networks, which operate under the restraints of physical laws.

KEYWORDS Machine Learning, Potentially Hazardous Objects, Minor Planets, Asteroids

IAUS 368

#3265

Detecting Strong Lensed Quasars and Measuring their Time Delays from the Unresolved Light Curves

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Strong gravitational lensed quasars (QSO) with multiple images can be the next frontier in cosmic probes. One can constrain crucial cosmological parameters, such as the value of Hubble constant, independent of other probes by measuring the time delays between the images. The ongoing and the upcoming time-domain surveys like ZTF, Rubin, Roman will observe a lot of lensed QSOs. However, many will have the images spatially unresolved, with the observed lightcurve a superposition of time-delayed image fluxes. The primary challenge in detecting lenses using the joint light curves arises from the fact that the temporal flux variability of QSOs is highly stochastic and not well understood yet. We introduced a completely data driven method that can identify the lensed QSOs and simultaneously measure the time delays only using the unresolved light curve data, most importantly without assuming anything about the flux variability, nor using any additional information. In this talk, I will describe this novel technique and demonstrate its performance on a variety of simulated unresolved systems, as well as on the existing data quality by considering the observed lensed QSO light curves monitored by the COSMOGRAIL team.

KEYWORDS Strong lensing, Statistics and data analysis, Time delay measurement, Cosmology

IAUS 368
#3162

Clustering analysis with stellar photometric data

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The huge amounts of data provided by stellar surveys offer an unprecedented opportunity for the detailed characterization of large stellar samples. Dealing with this amount of data and obtaining precise results from them is, however, not straightforward. When high-resolution spectra are available, one well-established approach to obtain precise stellar atmospheric parameters and abundances is the so-called differential analysis, where similar stars are analyzed with respect to each other. In our team, we are developing a new pipeline, called CHESS, that aims to obtain high-quality stellar parameters from the analysis of high-resolution spectra using differential analysis when possible. To make that efficient, the first step of the analysis is to identify similar stars in the sample. One way we are exploring to achieve that is to separate groups of similar stars by employing photometry in the first instance, putting together data obtained from catalogues of different surveys, and making use of as many colors and magnitudes as possible. In this poster, we discuss the preliminary results of an analysis using different clustering algorithms on this photometric data. We focus on a few open clusters to obtain our sample of stars but plan to extend the analysis to field populations as well. We also use photometric data for preliminary estimates of atmospheric parameters to guide the selection when possible. The photometry, however, can sometimes be inhomogeneous and incomplete. Here, we also discuss how these technical issues impact the analysis and present a test of the results with respect to parameters available in the literature.

KEYWORDS Machine Learning, Stellar Characterization, Photometry, Open Clusters

IAUS 368
#3161

Searching for similar stars in large spectroscopic datasets with machine learning

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Several large stellar surveys have been or will provide photometric, astrometric, and spectroscopic data key for the characterization of an impressive and ever-growing number of stars. To deal with and make the best use of this data deluge, there is the need to develop methods and tools that can help in determining stellar properties, including chemical abundances, with the highest possible precision. We have been working on a new spectroscopic analysis pipeline, called CHESS, to automate the steps needed to obtain high-quality stellar parameters and abundances. Precise abundances, for as many elements as possible, are key for studies of Galactic archaeology. One well-established approach to obtain high precision in the analysis of high-resolution spectroscopy is the so-called differential analysis, where similar stars are analyzed with respect to each other. However, in a large spectra dataset, one does not know a priori which are the best candidates for such differential analysis. Within our pipeline, we plan the first step with methods that can help us to choose the proper stars for differential analysis. In this poster, we present the first results of this similarity analysis which makes use of unsupervised machine learning algorithms (such as clustering and dimensionality reduction) applied directly to the stellar spectra. Our test sample is made of UVES spectra of stars in metal-poor ([Fe/H] ~ -1.3 dex) globular clusters, obtained from the ESO data archive. For the analysis, we consider each spectrum to be a point in a multi-dimensional space made of each data pixel. Parameters like spectral resolution, dispersion, flux scale, and wavelength range need to be made homogeneous. We tested different algorithms to identify similar stars without a priori information. We present a comparison between results obtained with different methods and test these results with respect to parameters available in the literature.

KEYWORDS Machine Learning, Stellar Characterization, Spectroscopy, Globular Clusters

Deep Learning Approaches to Large Scale Structure Cosmology

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The large scale structures (LSS) in the universe traced by luminous galaxies encode information on the cosmological model. Using cosmology simulations, we can observe the variation in the LSS caused by different cosmological parameters. Using machine learning, we can capture the character of each simulation and predict which cosmological parameter they contain. In this proof of concept work, we utilise the fast and approximate PINOCCHIO simulation code which is based on Lagrangian Perturbation Theory and produce realistic halos lightcones. With these simulations, we trained two different deep learning approaches, Convolution Neural Networks (CNN) and Vision Transformers (ViT) and compare their ability to extract cosmological information.

KEYWORDS Cosmology, Machine Learning, CNN, ViT, Large Scale Structure

IAUS 368

#2857

Unveiling the morphologies of z>3 with JWST and self-supervised learning

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The James Webb Space Telescope (JWST) will provide imaging of high-z galaxies with enough detail and sensitivity to unveil the rest-frame morphological properties of galaxies at z>3. The morphological distribution of galaxies at these redshifts is unknown.

In preparation for the first scientific data from the JWST (expected in mid 2022), we therefore propose the use of self-supervised machine learning based on deep contrastive learning to estimate galaxy morphologies without labels. We first calibrate a neural network model on a set of JWST-like galaxy images at z>3 extracted from the TNG50 cosmological simulation. We demonstrate that our approach successfully organizes galaxy images without supervision in a lower dimensionality space, showing correlations with physical properties such as specific angular momentum and kinematic decompositions of bulges and disks. Moreover, because the contrastive learning setting is trained on both noiseless and mock JWST images, it effectively learns patterns beyond the noise level.

Our framework is ready to be applied on the first JWST data in order to: 1) efficiently compare observations with the predictions of cosmological simulations; and 2) provide a first description of galaxy morphologies in a still unexplored redshift range.

KEYWORDS self-supervised learning, JWST, galaxy morphology

IAUS 368

#2845

Investigation of the orbital period and mass relations for W UMa-type contact systems

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New relationships between the orbital period and some parameters of W UMa-type systems are presented in this study. To investigate the relationships, we calculated the absolute parameters of a sample of 118 systems. For this purpose, we used the parallax values obtained from the Gaia EDR3 star catalog for more precise calculations. The other required parameters, including the light curve solutions and orbital period, were derived from previous research. for some relationships, we added 86 systems from another study with an orbital period of less than 0.6 days to our sample, allowing us to increase the number of systems to 204. Therefore, the mass (M) values of each component along with all the other absolute parameters were recalculated for these contact systems. We used the MCMC approach in order to gain the new orbital period-mass relations (P-M) per component and added the temperature (T) to the process to acquire the new orbital period-temperature (P-T1) relation. We presented the orbital period behavior in terms of log(g) by new relations for each component. We have also obtained a model between the orbital period, the mass of the primary component, and temperature (P-M1-T1) using the artificial neural network (ANN) method. Additionally, we present a model for the relationship between the orbital period and the mass ratio (P-q) by fitting a multilayer perceptron regression model to a sample of the data collected from the literature.

KEYWORDS binaries: eclipsing, binaries: close, stars: fundamental parameters

IAUS 368

#2801

Combining citizen science and machine learning strategies to enable Galaxy Zoo: Clump Scout science

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Citizen science is a proven method for obtaining training labels for machine learning in many astronomical contexts at intermediate scales of big data. However, to match the needs of next generation surveys both in scale and complexity, new methods for combining the power of humans and machines need to be developed. These include novel aggregators of volunteer annotations as well as machine learning-based anomaly detection techniques for serendipitous discovery. We discuss the advantages and challenges of these methods in the context of the recent citizen science project Galaxy Zoo: Clump Scout. The Clump Scout project, hosted on the Zooniverse platform, recruited more than 14,000 volunteers to identify clumps (massive, kiloparsec-scale regions of elevated star formation) in nearly 60,000 Sloan Digital Sky Survey galaxies. To identify these clumps, we use a novel aggregation technique specifically designed for reducing data from 2D volunteer annotations. Our technique statistically models for the annotation habits of each volunteer, as well as the difficulty of each subject, to derive a maximum likelihood solution for clump locations within our galaxy sample. Using confidence scores provided by this aggregation framework in addition to physically-motivated post-processing steps, we are able to identify genuine clumps in noisy volunteer-provided data. These labels are then used to train a machine model that can then be used to predict on new data sets from upcoming surveys. We also present a spatial “anomaly” analysis of clumpy galaxies using 2D anomaly score maps, which are computed by novel convolutional autoencoder and long-short term memory networks applied to MaNGA IFU datacubes. Comparing the physical properties of highly-anomalous spatial regions within clumpy galaxies to those from non-clumpy counterparts allows us to identify and study galaxy substructures of interest. Such anomaly detectors can be used for serendipitous discovery of extreme or distinctive subjects in future surveys, broadening the impact of citizen science efforts in the big survey era.

KEYWORDS Anomaly detection, Machine learning, Citizen science, Deep learning

IAUS 368
#2784

Deep Learning and numerical simulations to infer the evolution of MaNGA galaxies

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As surveys grow, the challenge is how to explore and interpret the increasing quantity of data. Integral field spectroscopic (IFS) galaxy surveys are a good example of how data have grown in complexity and in volume. In order to find complex relations between the spatially resolved structures of galaxies and their accretion histories, we combine IFS high-dimensionality data, deep learning and numerical simulations to infer the evolutionary paths of galaxies. In this work we generate 24,000 simulated galaxies from TNG50 hydro-cosmological simulation to compare with the 10,000 galaxies observed in MaNGA, thus generating a mock MaNGA sample. We then analyze how the simulated galaxies reproduce the properties of MaNGA galaxies and study how the evolutionary paths of the mock galaxies relate to their "observable" properties.

Removing the observational biases and reducing the dimensionality of the data are fundamental. A promising avenue to perform this comparison is an unsupervised Deep Learning algorithm called Contrastive Learning. Contrastive Learning is especially effective with noisy or biased data and produces a representation space that organizes the data by their similarity. Because the data complexity is much reduced in this representation space, it is very well suited to compare the simulated and observed galaxies. It also allows us to study merging and interacting galaxies, tracing significant events that shape the physical properties of the galaxies. Contrastive Learning allows us to analyze the distribution of common physical structures in the representation space and thus trace different stages of galaxy evolution.

KEYWORDS Deep Learning, Galaxy Evolution, Integral Field Spectroscopy, Cosmological simulations, Interacting galaxies

IAUS 368

#2670

CNN-TDA Net :
Focus adjustment toward persistent topological signal of point-source

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Convolutional Neural Network (CNN) is rising as a popular solution for many astrophysical studies such as real and bogus classification, gravity wave detection.

The outstanding feature of CNN is to detect local patterns in data.

This makes CNN learn the features of point-source in sky image efficiently.

However, this characteristic may lead to misunderstanding of noises or artifact errors like point-source as important patterns.

In this talk, we introduce CNN-TDANet, the multi-modal convolutional neural network to make CNN learn not only local patterns but also global structures in image.

Our approach is based on persistent homology theory that is the main tool of topological data analysis.

Using this, it is possible to effectively summarize the global structure for the connectivity of pixels and loops in the image.

We notice that the point-sources have long-persistence, but noises and artifacts have short-persistence with respect to persistent homology theory.

We transform this information as several types of vectors in order to put them in neural networks.

The essential architecture of CNN-TDANet is concatenating CNN for images and TDA Network for topological vectors.

We compare CNN-TDANet with previously reported CNN architecture for real/bogus classification.

We show the experimental results that our CNN-TDANet performs better than existing CNN and weights the features nearby the point-source object.

KEYWORDS Real/bogus classification, machine learning, deep learning, convolutional neural network, topological data analysis

IAUS 368
#2643

Fully Adaptive Bayesian Algorithm for Data Analysis. FABADA

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The aim of this talk is to describe a novel non-parametric noise reduction technique from the point of view of Bayesian inference that may automatically improve the signal-to-noise ratio of one- and two-dimensional data, such as e.g. astronomical images and spectra. The algorithm iteratively evaluates possible smoothed versions of the data, the smooth models, obtaining an estimation of the underlying signal that is statistically compatible with the noisy measurements. Iterations stop based on the evidence and the chi-square statistics of the last smooth model, and we compute the expected value of the signal as a weighted average of the whole set of smooth models. In this talk, we will explain the mathematical formalism and numerical implementation of the algorithm, and we will show its performance in terms of the peak signal to noise ratio, the structural similarity index, and the time payload, using a battery of real astronomical observations.

Our Fully Adaptive Bayesian Algorithm for Data Analysis (FABADA) yields results that, without any parameter tuning, are comparable to standard image processing algorithms whose parameters have been optimized based on the true signal to be recovered, something that is impossible in a real application. State-of-the-art non-parametric methods, such as BM3D, offer slightly better performance at a high signal-to-noise ratio, while our algorithm is significantly more accurate for extremely noisy data (higher than 20-40% relative errors, a situation of particular interest in the field of astronomy). In this range, the standard deviation of the residuals obtained by our reconstruction may become more than an order of magnitude lower than that of the original measurements. The source code needed to reproduce all the results that will be presented, including the implementation of the method, is publicly available at https://github.com/PabloMSanAla/fabada

KEYWORDS Image denoising, Bayes' methods, Data analysis

IAUS 368

#2637

Searching for Globular Cluster Candidates around M81, M82, NGC3077 Using Machine Learning Techniques

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Globular clusters are excellent records of the interacting history of galaxies. Such an event can be seen in the center of a nearby M81 group of galaxies, in which their recent close encounters have stripped off their stars and interstellar materials into their halo. Recent studies have identified several globular clusters and globular cluster candidates in M81. However, those in the large galactocentric distance are still missing. In this study, we apply machine learning-based data clustering and data classification techniques to the CFHT archival data of the M81 group to search for new halo globular cluster candidates. The data cover the central region of the group and include three main galaxies, M81, M82, and NGC3077. Understanding the characteristics of the halo globular cluster candidates will provide more insight into the interacting history of the galaxies.

KEYWORDS Extragalactic globular clusters, galaxy: M81, machine learning

IAUS 368

#2614

Multi-scale deep learning for estimating horizontal velocity fields on the solar surface

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The dynamics in the solar photosphere is governed by turbulent convective motions. It is important to derive three-dimensional velocity vectors to know the nature of the turbulent convection. The line-of-sight component of the velocity can be obtained by observing the Doppler shifts, but it is difficult to obtain the velocity component perpendicular to the line-of-sight which corresponds to the horizontal velocity. We develop a convolutional neural network model to infer the horizontal velocity fields. The model is based on a multi-scale deep learning architecture that consists of multiple convolutional kernels with various sizes of the receptive fields and performs convolution for both the spatial and temporal axes. The network is trained with data from three different numerical simulations of turbulent convection. We also newly introduce the coherence spectrum to assess the horizontal velocity fields thus derived at each spatial scale. The multi-scale deep learning method successfully predicts the horizontal velocities for each convection simulation in terms of the global correlation coefficient. However, the coherence spectrum reveals the strong dependence of the correlation coefficients on the spatial scales. Although the coherence spectra are higher than 0.9 for large-scale structures, they drastically decrease to less than 0.3 for small-scale structures, wherein the global correlation coefficient is about 0.95. These results imply that the accuracy for the small-scale structures is not guaranteed only by the global correlation coefficient. To improve the accuracy on small scales, it may be worth improving the loss function to enhance the small-scale structures and to utilize other physical quantities as input data related to the non-linear cascade of convective eddies.

KEYWORDS solar photosphere, convection, deep learning

IAUS 368
#2605

How and why TDA improves CNN: Transient vs Bogus classifications

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Topological Data Analysis (TDA) characterizes the global structure of data based on topological invariants, while Convolutional Neural Network (CNN) is capable of characterizing local features. A combined model of CNN-TDA Net, a family of multimodal networks, that takes the input image and the corresponding topological features simultaneously together for classification problems, significantly improves the CNN performance. Although its success has recently been reported in various applications, however, there is a lack of explanation as to why how topological features improve the discriminative power of the original CNN. In this talk, we demonstrate the effects of topological features on a CNN using Transient vs Bogus classification and gravitational wave detection problems with Grad-CAM analysis. With Grad-CAM analysis on multimodal networks, we demonstrate that adding topological features enforces a CNN to concentrate on more important regions across images than task-irrelevant artifacts such as background and texture.

KEYWORDS Transient Classification, Supernove Classification, CNN, TDA, Grad-CAM

IAUS 368
#2582

Reconstructing the early universe using CMB temperature and polarization

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We reconstruct the functional form of primordial power spectrum using the cosmic microwave background data from Planck. Our method builds on the modified Richardson-Lucy algorithm to include both temperature and polarization data while accounting for non-diagonal covariance. We find that the reconstructed spectrum not only significantly improves the fit to data, but also tends to favor small deviations away from the near scale-invariant spectrum. Such features are supported by many physically well-motivated inflation models. We discuss several different regularization methods to avoid overfitting.

KEYWORDS Early Universe, CMB, Primordial Power Spectrum, Reconstruction, Primordial Features, Regularization, Richardson-Lucy Deconvolution

IAUS 368

#2580

Joint reconstructions of growth and expansion histories with Gaussian Processes: Dark Energy beyond Λ

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Using forecasted Supernovae (SN), Baryon Acoustic Oscillations (BAO) and Redshift Space Distortions (RSD) measurements from the next generation of (stage-IV) cosmological surveys, we jointly reconstruct the growth and expansion histories with Gaussian Processes. Our approach relies on few (reasonable) assumptions, namely: (i) an FLRW metric and (ii) an Einstein De Sitter Universe at high-redshift. We forecast the future surveys' potential to accurately reconstruct the Dark Energy (DE) evolution and thus to detect any possible deviation from a cosmological constant Λ. We generate mock data for various alternative DE models, and illustrate how our method captures the correct DE behaviour in all cases.

KEYWORDS Dark Energy, Gaussian Processes, Machine Learning, Non-parametric reconstructions, Cosmology

IAUS 368
#2563

A classification algorithm for time-domain novelties in preparation for LSST alerts

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With the advent of Vera Rubin Observatory's Legacy Survey of Space and Time (LSST), time-domain astronomy will be faced with an unprecedented volume and rate of data. Real-time processing of variable stars and transients detected by such large-scale surveys is critical to identifying the more unusual events and allocating scarce follow-up resources efficiently. In this poster, we highlight the statistical algorithm we have developed to identify these novel events within a given population of variable sources. We present the results of its application to a sample of a few thousand variable sources identified from the DECam Galactic Bulge survey and to the real-time alert data of the ongoing Zwicky Transient Facility survey using the community alert broker ANTARES.

KEYWORDS LSST, Anomaly detection, Time-domain astronomy

IAUS 368

#2549

3-day Forecasting of Global TEC Maps Using a Deep Learning Model

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In this study, we develop a deep learning model to make a time-series forecasting of global Total Electron Content (TEC) maps using an image-to-image translation method based on conditional generative adversarial networks. For training our deep learning model, we use the International GNSS Service (IGS) TEC maps from 2003 to 2012. Our model uses two input data (t-12 and t+0 IGS TEC map) and generate 6 TEC maps with a cadence of 12 hours (t+12, t+24, t+36, t+48, t+60 and t+72). And sequentially shifting two hours back input data to generate the output data. Then combine all the outputs. Finally, our model provides a time-series forecasting up to 72 hours with 2-hour time cadence. Our models are tested for solar maximum period (2013-2014) and minimum period (2017-2018) data. For evaluation we compare our model results and IGS TEC maps using Pearson correlation coefficient (CC), root mean square error (RMSE), bias, and standard deviation (STD). The results of one-day forecasting predicted by our models are 0.98, 2.57 TECU, -0.13 TECU and 2.45 TECU for mean CC, RMSE, bias and STD, respectively, which are better than the previous models. Our study shows that a set of deep learning models successfully generate a time-series forecasting of TEC maps.

KEYWORDS TEC, Deep learning

IAUS 368

#2553

Application of image translation methods based on deep learning to denoising solar magnetograms

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In astronomy, long exposure observations are one of the important ways to improve signal-to-noise ratios. In this study, we apply image translation methods based on deep learning to denoising solar magnetograms. For the input magnetogram, we use SDO/HMI line-of-sight magnetograms at the center of solar disk. For the target magnetogram, we make 21-frame-stacked magnetograms considering solar rotation at the same position. We train a model using 7004 pairs of the input and target magnetograms from 2013 January to 2013 October. Then we validate the model using 707 pairs in 2013 November and test the model using 736 pairs in 2013 December. Our results from this study are as follows. First, our model successfully denoises SDO/HMI magnetograms and the denoised magnetograms from our model are mostly consistent with the target magnetograms. Second, the average noise level of the denoised magnetograms is greatly reduced from 8.66 G to 3.21 G, and it is consistent with that of the target magnetograms, 3.21 G. Third, the average pixel-to-pixel correlation coefficient value increases from 0.88 (input) to 0.94 (denoised), which means that the denoised magnetograms are more consistent with the target ones than the input ones. Our results can be applied to many scientific fields in which the integration of many frames (or long exposure observations) is used to improve the signal-to-noise ratio.

KEYWORDS Sun, Solar, Magnetogram, Magnetic field, Deep Learning

IAUS 368
#2514

Versatile morphological classification for the next generation of large surveys

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Galaxy morphology is a fundamental quantity that is essential not only for the full spectrum of galaxy evolution studies, but also for a plethora of science in observational cosmology. While a rich literature exists on morphological-classification techniques, the unprecedented data volumes, coupled, in some cases, with the short cadences of forthcoming 'Big-Data' surveys (e.g. from the Rubin Observatory and SKA), present novel challenges for the field. Large data volumes make such datasets intractable for visual inspection (even via massively-distributed platforms like Galaxy Zoo), while short cadences make it difficult to employ techniques like supervised machine-learning, since it may be impractical to repeatedly produce training sets on short timescales. Unsupervised machine learning, which does not require training sets, is ideally suited to the morphological analysis of new and forthcoming surveys.

We employ an algorithm which utilises graph representations to efficiently cluster small patches of an image by their visual properties. We then construct a feature vector which describes the frequency with which certain types of patch appear in a given object, thus allowing us to measure their visual similarity. We demonstrate the versatility of this approach, which allows us to, for example, identify similar or dissimilar objects to a given real object or synthetic feature vector, identify unusual or outlying objects or group objects with similar morphology by clustering their feature vectors.

We implement our algorithm on the Hyper-Suprime-Cam Subaru-Strategic-Program Survey to autonomously reduce the galaxy population to a small number of 'morphological clusters', populated by galaxies with similar morphologies, which can be rapidly benchmarked via visual inspection. The morphological classifications reproduce known trends in key galaxy properties as a function of morphological type. Our study demonstrates the power of unsupervised machine learning in performing accurate morphological analysis, which will become indispensable in this new era of deep-wide surveys.

KEYWORDS Unsupervised Learning, Morphology, Big Data

IAUS 368

#2489

Revealing celestial variable sources with Gaia DR3

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The Gaia Third Data release unveils a very diverse and large harvest of variable sources. Indeed the multi-epoch nature of the Gaia mission, with its measurements in different instruments, allows us to perform a systematic and quite unique analysis of the observed sources in terms of their variability. The Gaia mission provides one of the most complete and extended multi-epoch surveys over the whole sky.

For Gaia DR3, we analysed 34 months of data for 1.8 billion sources, and we provided a catalogue of 10.5 million variable objects with associated time series in the G, G_BP, and G_RP bands. The radial velocity time series of about 2,000 Cepheids and RR Lyrae stars are further provided. This global processing and analysis of Gaia data are doing ample usage of Machine Learning technics.

The catalogue contains 23 types of variable stars, from the small variations of exoplanetary transits to the exploding Supernovae. We further provided inputs to the QSO Gaia catalogue and also identified 2.5 million galaxies thanks to a photometric perturbation induced by these extended objects.All these data are available in the Gaia archive on the ESA website or other data centres.

In this talk, we present the analysis with a summary of the results with some highlights.

KEYWORDS Time Domain Astronomy, Machine learning methods, large survey, Gaia, variable stars, AGN, galaxies

IAUS 368

#2470

CORTEX - the Center for Optimal, Real-Time Machine Studies of the Explosive Universe

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Many elements important for life and technology are only formed in the Universe when two neutron stars coalesce. These catastrophic mergers remains a mystery due to great observational challenges: they are only visible for a few seconds. The 24/7 measurement data rates exceed those of entire countries, and need to be analyzed within seconds. In CORTEX, we combine fundamental research in key areas (algorithms, pipelines, merger physics, and radio astronomy) with real-life development (accelerators, complex self-monitoring systems) to shed light on gravitational-wave bursts.

This research aims to understand how deep neural networks can be made more efficient, and demonstrate how auto-tuning, selfmonitoring, data-driven pipelines, on highly parallel accelerator hardware, produce optimal results. Deep neural networks are increasingly being relied on for science, including physics and astronomy; but the tremendous data rates involved in the physical sciences are a challenge. This means that many detection pipelines no longer reach real-time performance. I will present the investigations in CORTEX on meeting real-time demands, guided by a number of our recent publications in mathematics, computer science, physics, and astronomy. These range from Bayesian GPU optimization to fast gravitational wave localisation, plus radio-transient and FRB searches and detections.

KEYWORDS Gravitational waves, Machine learning, Accelerators

IAUS 368
#2415

Machine-learning detection of false-positive solutions in the inversion of asteroid sparse-in time photometry

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Shapes and spin states of asteroids can be reconstructed from their time-resolved photometric measurements. The light curve inversion techniques have been developed during the last two decades and have become standard tools when reconstructing asteroids' spin and shape from photometry. Current sky surveys provide photometric data in the form of so-called sparse-in-time photometry - the sampling is sparse with respect to the periodicity of the signal, which is given by the asteroid's rotation period. The inversion of such sparse photometry is computationally demanding because a huge parameters space has to be searched for the globally best solution. A critical step on the way from data to model is the decision if the formally best solution with the lowest residuals is statistically significant concerning other local minima in the parameter space. Another important step is to check if the solution is physically realistic. False-positive solutions are usually detectable by visual inspection of the asteroid shape model, the structure of the periodogram, and other relevant parameters. However, this approach is not only time-consuming, not well documented, and subjective, but most importantly, not practically applicable when the number of models is large. It can be hardly done in practice for thousands of new models that we have recently reconstructed, not to say for those models that will be reconstructed from Gaia DR3 or LSST in the future. Therefore, developing fully automated algorithms that would reliably work without human interference is necessary. Machine learning algorithms seem like ideal tools for the reliable automatic removal of incorrect models. We will describe our tests of applying random forests and neural networks to this problem and discuss prospects for the future.

KEYWORDS asteroids, lightcurves, photometry

IAUS 368
#2348

Stellar spectra classification and clustering using deep learning

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Most of our knowledge about the Universe comes from the careful analysis of light that reaches us. Spectroscopy, which is the most detailed method of spectrum analysis, when applied to stars provides information on the parameters of their atmospheres, including effective temperature, acceleration, velocity fields, and their chemical composition. Stellar classification brought forth the understanding what physical parameters are critical in shaping stellar atmospheres. It is a key element that has linked efforts related to numerical modeling of atmospheres with observations.

We present a method of a robust stellar spectra classification which is based on large-scale unsupervised pre-training. The applied deep neural network of the autoencoder type, thanks to the use of differentiable elements of physical modeling in the decoder, allows to work with low to high resolution spectra, is insensitive to normalization errors, different radial and rotational velocity, and operates in a wide range of signal-to-noise ratio. Finally, we performed clustering in its latent space and compared obtained groups with the classical classification, indicating the differences and similarities between the results.

KEYWORDS stellar spectroscopy, classification, clustering, deep learning

IAUS 368
#2276

Radio image segmentation with variational autoencoders: application to SKA Data Challenge 1

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Source detection and classification are challenges for large-scale radio surveys and will become more so as we move towards the era of the SKA. We have been experimenting with a machine-learning approach to detecting and classifying the full radio source population in the SKA Data Challenge 1 dataset using a Variational Autoencoder (VAE) to effect image segmentation. The trained network reconstructs the raw image data as a binary segmentation map that describes the angular size, ellipticity, position angle, and location of the source. Source classification can be performed in the latent space of the network using appropriate latent vectors. This work serves as a proof of concept that a VAE can detect and classify radio source populations from SKA-like data.

KEYWORDS surveys, VAE, machine learning

IAUS 368

#2250

High-redshift galaxy cluster candidates from Subaru HSC photometric redshifts

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To better understand the the phenomena of Gamma-Ray Bursts in high-redshift host galaxies we have to know not only the distance of the host galaxy itself from us but the location of the host in its own galaxy cluster. Recent theories linked long GRBs to galaxies with rapid star formation or starburst, thus we except GRBs are more frequent in midcluster galaxies where tidal interactions between gas-rich galaxies are more likely to occur. Using different statistical and machine learning methods on deep Subaru Hyper Suprime-Cam observations we are giving constraints on photometric redshifts of galaxy clusters to place these host galaxies in their local environment.

KEYWORDS galaxies: clusters, galaxies: distances and redshifts, methods: statistical, methods: data analysis, gamma-ray burst

IAUS 368

#2248

Can the distance of GRBs be estimated using machine learning?

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The number of ground-based redshift measurements of GRBs are decreasing year by year. The physical parameters measured from the emission from the objects depend on the distance, but the effect is less than the GRB's own variability. Also, the mechanisms are complex and difficult to determine by simple statistical methods. Nevertheless, we obtained promising results for estimating redshifts by machine learning. It is possible to distinguish the z<4 and z>4 GRBs with an almost 90% goodness of classification.

KEYWORDS gamma-ray burst: general, galaxies: redshifts, cosmology: large-scale structure of Universe, methods: statistical, methods: data analysis

IAUS 368
#2124

Data pre-extraction for better classification of galaxy mergers

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Galaxy mergers a central to our current understanding of the universe. In the current dark matter paradigm, dark matter halos merge with one-another, resulting in baryonic components, the galaxies, also merging. These powerful events are known to radically change the morphologies of the merging galaxies, both during the merger event as well as the resulting morphology of the merged galaxy. These morphological shifts and disturbances are also accompanied by changes to the physical processes going on inside the galaxies. For example, mergers are known to trigger star-bursts as well as increase AGN activity. However, galaxy mergers are rare events and to better study them we need larger, statistical samples.

The increased used of machine learning and artificial intelligence has seen galaxy mergers becoming a target of study for these techniques. In the last four or five years, application of these techniques have gone from simple proof of concept to using machine learning galaxy merger catalogues for science. However, these classifications are not without issues, often high contamination of the merger sample. Thus, we need ways to improve our classification.

In this presentation, I will explore how we can use images of galaxies to identify galaxy mergers. Specifically, I will look at how extraction of morphological parameters by traditional methods can be used to aid neural networks in classification of galaxy mergers. We will see how current neural networks may not be fully extracting all the information from imaging data. I will also discuss how samples of rare objects can be contaminated and the impact this can have on our science.

KEYWORDS Galaxies, Galaxy Merger, Galaxy morphology, Galaxy Interactions, Machine Learning, Deep Learning

IAUS 368

#2053

Retrieving cosmological information from clusters and hot diffuse gas in CMB small scales using machine learning emulator of power spectrum

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Planck experiments have observed galaxy clusters using their SZ signature but was also able to produce maps of the full hot gaz distribution in the sky (including clusters and more diffuse components). The SPT data at very small scales are known to probe not only primordial CMB fluctuations but also many extragalactic components such as tSZ, kSZ, CIB, points sources.

I will show how to use the cosmological dependent SZ signature at small scales coherently with the large scales and the cosmology framework in these two experiments to retrieve both cosmological parameters and cluster scaling relations. Using machine learning to compute efficiently the SZ angular power spectrum, I will show new constraints obtained using SPT CMB observations combined with the latest Planck observed tSZ spectrum and compare them with constraints obtained with cluster number counts. I will discuss how such a coherent analysis could bring additional cosmological information and shed light on the sigma8 tension observed between CMB and clusters.

KEYWORDS cosmology, emulator

IAUS 368

#1921

Unraveling galaxy merger histories with deep learning

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Mergers between galaxies can be drivers of morphological transformation and various physical phenomena, including star-formation, black-hole accretion, and chemical redistribution. These effects are seen clearly among galaxies that are currently interacting (pairs) -- which can be selected with high purity spectroscopically with correctable completeness. Galaxies in the merger remnant phase (post-mergers) exhibit some of the strongest changes, but are more elusive because identification must rely on the remnant properties alone. I will present results from my recent paper combining images and stellar kinematics to identify merger remnants using deep learning (arXiv:2201.03579). I show that kinematics are not the smoking-gun for improving remnant classification purity and that high posterior purity remains a significant challenge for remnant identification in the local Universe. However, an alternative approach which treats all galaxies as merger remnants and reframes the problem as an image-based deep regression yields exciting results.

KEYWORDS galaxies, mergers, imaging, kinematics, deep learning, machine learning, data science

IAUS 368
#1730

Unsupervised clustering visualisation tool for Gaia DR3

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Gaia mission is providing accurate data on the astrometric and spectrophotometric properties of around two billion stars in the Galaxy, and several hundred million extragalactic objects. DPAC international consortium oversees data processing and handles delivering usable scientific information to the community.

Among the products provided in the archive is the classification of the sources into the main astronomical classes of objects and an analysis of the classification outliers. For this purpose, our group has developed a technique based on unsupervised learning, Self-Organizing Maps (SOM), which provides a grouping of these objects into element samples whose common properties are used to provide prototypical objects and statistics of Gaia the measurements on them. SOM provides excellent quality grouping as well as a non-linear dimensionality reduction, by projecting the input data in a determined number of neurons or clusters, usually arranged in a two-dimensional lattice, preserving the topology.

One of the main difficulties of this technique relies on the analysis of the maps, related to the physical and statistical properties of the clustered objects, containing neurons populated with millions of inputs in a Big Data scenario like Gaia. To ease an in-depth study of the content of the map and their neurons, we developed a visualisation tool, GUASOM, published with the DR3 of Gaia.

This tool has been developed using Web technologies in a client-server architecture, in which, the frontend has been developed as a Web application using Angular and the backend has been developed as a REST server using Spring.

Concurrent access is expected, involving a wide variety of data in a Big Data scenario that must be delivered in short periods of time, and for that reason, all the data involved must be prepared in advance in simple, sorted, and efficient data structures having only the information requested by the users.

Moreover, this tool must supply information that allows the scientific personnel to analyse the data behind the scenes, and to do that, it is mandatory to provide some specialized visualizations that highlight the physical content of the data obtained from the Gaia catalogue as well as other well-known catalogues through crossmatch procedures.

KEYWORDS Big data Astronomy, Self-Organising Maps, Unsupervised learning, Visualisation, Gaia mission

IAUS 368

#1676

A Machine Learning-based DPAC algorithm for Gaia RVS spectra parameterization

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Machine learning techniques are becoming in useful tools in many fields where massive data analyse are needed. That is specially true where no nalytical form of the likelihood exists or when its evaluation is computationally expensive. In this work we present one of the two methods implemented in the Gaia data processing system for the analysis of the RVS spectra. This method consist in an Artificial Neural Network (ANN) able to infer the stellar effective temperature, log-gravity, alpha-enrichment and metalicities through the measured spectra. To build the ANN different spectra was simulated using theoretical models and was smeared by adding noise-signals to achieve different degrees of signal-to-noise (S/N) ratio. With this procedure the network can be used on actual measured spectra without the necessity of preprocessing steps. As a result, different ANNs are applied on data depending of the S/N. At the end of the process, calibrations on the inferences and uncertainties are studied using both new simulated spectra and a set of spectra with well known stellar parameters measured by other surveys. Moreover, a brief explanation on how to obtain published inferences provided by the ANN as part of the Gaia DR3 is shown.

KEYWORDS Artificial Neural Network, Machine learning, Gaia DR3, data analysis, stellar parameters, stellar atmospheres, spectroscopy

Is GMM effective in membership determination of Open Clusters?

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Determination of membership of star clusters is a very important criterion in their study as they effect determination of cluster parameters like radius, age, distance, mass functions, etc. In this paper, we apply the unsupervised method of Gaussian Mixture Modelling (GMM) to find membership of 9 open star clusters of varying ages and locations in the galaxy using Gaia DR2 and EDR3 data. We compare our results to help understand the efficiency of GMM. We find that this method works well with relaxed clusters with ages larger than their relaxation times as that is when they approximate a Gaussian better.

KEYWORDS Machine Learning, GMM, Gaia EDR3, Star Clusters, Membership

IAUS 368

#1678

Bayesian deconvolution of a rotating spectral line profile to a non-rotating one

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Nowadays, one of the standard procedures to determine stellar and wind parameter of massive stars, is to compare the observed spectral lines with synthetic ones. These synthetic spectral lines are calculated using state-of-the-art NLTE radiative transport codes with hydrodynamic velocity and density profiles used as input.

We developed a grid of models using the CAK theory for the hydrodynamics with our code HYDWIND. These outputs were used as input in the code FASTWIND to obtain the synthetic lines. Our database, called ISOSCELES has more than ½ million of models covering the spectral types OBA. All these models are calculated for a non-rotating star.

In this standard procedure, after measuring the rotational speed, all synthetic models are convolved with this rotational speed value. Once this is done, we can compare our observed line with the grid of models, task that is very time consuming and the whole convolution process must be repeated when another star (with other rotational speed) is analyzed.

In this work, we propose a methodology to deconvolve the observed line to a line of a non-rotating star. Therefore, we can use different machine learning techniques applied only to the 'original' (non-rotating) grid, sparing then significant time resources.

This is a very difficult inverse problem, describing by Carroll (1933) and our proposed deconvolution method is to transform this to the optimization of a direct problem. We propose that the non-rotating line can be described by a superposition of gaussians and convoluted them (with the measured rotational speed) to obtain the 'rotating' line and compare it directly with the observed line(s). We implemented the Hamiltonian Monte Carlo code "Stan" to solve this problem. The encouraging results for emission, absorption and P-Cyg lines present ubiquitously in massive stars spectra are shown, also some results for stellar and wind parameters of a sample of massive star. For a future work, we can apply convolutional neural networks to learn the grid of models and rapidly find stellar and wind parameters.

KEYWORDS Bayesian techniques, Monte Carlo, Massive Stars, Stellar rotation, Stellar and wind parameters, deconvolution

IAUS 368

#1260

Flare detection with different machine learning methods

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Stellar flares are an important aspect of magnetic activity - from both stellar evolution and circumstellar habitability viewpoints - but automatically and accurately finding them is still a challenge to researchers in the big data era of astronomy. I present our struggles to automate this task using both classical machine learning methods (RANSAC) and neural networks, and how these tools open doors for researchers to new possibilities and surprising new problems.

KEYWORDS flares, magnetic activity, deep learning

IAUS 368

#1551

Accelerating spectro-photometric modeling for next-generation massive surveys

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Measuring precisely and accurately the physical properties of galaxies is critical for understanding their formation and their evolution. Much of this information is intimately intertwined within their panchromatic emission. To extract this information, over the past decade there has been an intense development of new codes modeling the spectro-photometric emission of galaxies. One of these codes is CIGALE (Code Investigating GALaxy Evolution). It is a panchromatic (from the X-rays to the radio), Bayesian fitting code written in Python. Its modularity and flexibility makes it adaptable to a large variety of use cases. Parallel and carefully optimized, it is fast both for computing grids of models and fitting them to observations and estimate physical properties. However, next-generation surveys such as LSST, represent a staggering challenge for modeling codes. The sheer number of galaxies that will be detected, billions, means that even the fastest codes are not up to the task when it comes to modeling in a timely fashion these many galaxies. Thankfully new techniques hold considerable promise for greatly accelerating this step. I will present two on-going initiatives to address this challenge with CIGALE. First, I will show new developments using Adaptive Importance Sampling, which considerably reduces the number of models to be computed to estimate the physical properties, in combination with a simple neural network implementation to accelerate part of the model computations. Then I will present an alternative approach using Self-Organizing Maps, a dimension reduction technique to simplify the parameter space and also diminish the number of models to be fitted. Finally, I will provide a brief discussion of the respective advantages and drawbacks of these techniques in the context of massive next-generation surveys.

KEYWORDS machine learning, dimensionality reduction, statistics, galaxies, spectro-photometric modeling, massive surveys

IAUS 368

#1529

ANN based MCMC pipeline for constraining cosmological and astrophysical parameters using EoR observations

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We are planning to develop an Artificial Neural Network-based MCMC pipeline to constrain both astrophysical and cosmological parameters simultaneously, using CMB, 21-cm power spectrum, and reionization related observations, based on a recently developed photon-conserving semi-numerical reionization model called, SCRIPT. However, before producing the reionization map, SCRIPT requires an underlying density field in its input along with the astrophysical parameters. This implies that in order to run the MCMC code, we have to generate the density-field along with the reionization map as a function of

redshift for each and every point in the parameter space (as the underlying density-field depends on the cosmological parameters). Although SCRIPT is sufficiently fast, the computation of the underlying density field even using 2LPT based method (such as using MUSIC) for each point in parameter space requires a time of the order of a few minutes. This makes the MCMC run extremely time consuming and therefore almost impossible with the currently available computing equipment. Therefore, we are planning to use an ANN-based emulator instead of the actual code (density-field generator+

SCRIPT), which will make the run extremely efficient, and therefore make the MCMC run possible.

KEYWORDS ANN, Reionization, First stars, Cosmic Dawn, Cosmology

IAUS 368

#1437

Machine Learning Tools Applied to All-Sky Astroclimate Analysis in Romania

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Machine learning (ML) tools provide methods of filter, distinguish and extract patterns from the data, which further allows an efficient analysis of large data sets. Within the Meteoroids Orbits Reconstruction by Optical Imaging Network (MOROI), raw data represented by images of the sky are collected routinely since 2017 [1, 2]. Thus, automatic tools are needed to increase the data quality when calibrating¬ fireballs, and to classify images when conducting astroclimate analysis. In this study, a set of ML methods are compared for their ability to classify the night time all-sky images according to their level of cloud coverage.

First, the monochrome images recorded by the MOROI station installed at the Berthelot observatory [3] were processed, and a set of high level features were extracted from the data. Next, a supervised validation was employed to assign labels according to one of three levels of cloud coverage. Finally, a set of ML methods suited for data classification were applied, and tuned to obtain an accuracy ranging between 88-94% for three group classification. The variation in scores depends on how the classes are defined, when the night time is set to begin, or other image recognition-specific difficulties. We discuss several methods to circumvent these problems and improve the score.

These tools are to be applied to filter the calibration data and conduct astroclimate studies on other stations within the Fireball Recovery and InterPlanetary Observation Network (FRIPON) worldwide consortium [4].

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[2] Anghel S., et al., 2021, LPI Contributions 2609 (2021): 6027

[3] Birlan M., et al., 2021, RoAJ, 31, 41

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KEYWORDS machine-learning, astroclimate, cloud, fireball, meteor, FRIPON, ML

IAUS 368
#1405

A survey of stellar populations in Ultra-Diffuse Galaxies (UDGs) in the era of LSST and JWST: the role of machine learning in finding and characterising UDGs

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Ultra-diffuse galaxies (UDGs) have been in the spotlight since their discovery in 2015. These galaxies defy our understanding of the whole field of galaxy formation and evolution as they have the sizes of giants, but luminosities of dwarfs.

Although UDGs have been heavily studied in the past years, most works have relied on spectroscopy to understand their stellar population properties, which is extremely difficult for such faint sources. In the era of ground- and space-based photometric sky surveys, a method to explore and unravel the properties of UDGs without relying solely on spectroscopy becomes a must.

In this work, we employ SED fitting techniques on data from the optical to the mid-infrared wavelength regime to recover the stellar population properties of 20 UDGs distributed across different distances and environments. We show not only that SED fitting allows us to recover stellar populations similar to those found spectroscopically, but we also show for the first time that UDGs display a bimodality in stellar populations tightly correlated to the environment that they reside in, meaning that UDGs found in different environments may be the result of different formation pathways. Moreover, we probe for the first time the presence of dust in UDGs, finding mild evidence of its presence throughout the sample. As a final result, we show that we can recover photometric redshifts for the UDGs consistent with the spectroscopic ones.

This technique, coupled with machine learning methods to find UDG candidates throughout the sky, can help to increase steeply the number of known UDGs and their stellar population properties, turning possible to test different formation scenarios and to understand the true nature (or rather multiple natures) of this new class of galaxies.

This work paves the way for finding and characterising UDGs via AI techniques by combining the large coverage of the sky provided by the future Vera Rubin Telescope, with the excellent capabilities of recovering photometric redshifts with the James Webb Space Telescope.

KEYWORDS ultra-diffuse galaxies, galaxies: formation and evolution, machine learning

IAUS 368

#1380

Cosmological Information from Higher Order Clustering Statistics

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The N-point spatial correlation function is a commonly used method of compressing the information of the large-scale distribution of galaxies. It can be used to extract the background expansion information via a standrad ruler (scale) known as the BAO, and growth of structure information via redshift-space distortions. Theoretical models of the higher order statistics are notoriously difficult to predict. In this work we will look at the cosmological information contained in the higher order clustering statistics upto the 4th order using a suite of N-body simulations as our theoretical model. We apply this methodology to the SDSS CMASS sample of galaxies, and compare with previous results. We also make forecasts for future data from DESI.

KEYWORDS Cosmology, Large Scale Structure, Higher Order Statistics

IAUS 368
#1360

Deep learning proves to be an effective tool for detecting previously undiscovered exoplanets in Kepler data

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Using deep learning with the Adam optimization algorithm in this research, I detected 11 previously undiscovered exoplanets in the Kepler data. Although some of the exoplanet transit signals were evident, others were not as strong and need further evaluation. By using my own code, open source libraries, and deep learning packages such as TensorFlow and implementing the Adam algorithm as an optimizer, I developed a Python program for exoplanet detection. The program first normalizes the transit light curves, trains the deep learning model using the Adam optimizer, folds the transit light curves to intensify the transit signals, then uses the model to search for exoplanet transits in the Kepler light curves. Among the newly detected exoplanets, 9 of them are ultra-short period (USP) exoplanets with orbital periods shorter than a day, and the 2 others are short period exoplanets with periods between 1 to 10 days. Because the Kepler mission lasted for nine years and observed each star for a selected period of time, there are much more Kepler Objects of Interest (KOI) with shorter periods than those with long periods in the NASA database. This may be a reason why the orbital periods of the detected exoplanets in this study are shorter than 10 days. Meanwhile, the detection of these new exoplanets, especially the USP exoplanets, can shed light on their kind and expand our views on their planetary systems, which possess different features than our Solar System. Finally, these findings show that artificial intelligence such as deep learning can be an effective technological tool to detect objects of interest in astronomy big data.

KEYWORDS exoplanet discovery, deep learning, Kepler, TensorFlow, Adam optimization algorithm, ultra-short period exoplanet, short period exoplanet

IAUS 368
#1299

A study on representation of Gravitational Waves Data for Convolutional Neural Network

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Machine learning keeps showing to the scientific community its capability at solving astrophysical problems. The LIGO-Virgo-KAGRA network is reaching sensitivities that could enable one detection per day (Abbott et al. 2020). With this amount of data to analyze, new consistent tools are needed. Binary Neutron stars mergers (BNS) are of particular interest for the possibility of multi-messenger astronomy. This practice requires fast computations for having the chance of a follow-up in different observing bands. With this short study, we investigate if BNS gravitational waves trigger detection should be preferably conducted in a representation instead of another, specifically we inspect time strains, Fourier transform, and spectrograms. Convolutional Neural networks (CNN) have been demonstrated to be a robust architecture in a variety of applications. These models can evaluate one-dimensional data as well as two-dimensional representations. We recreate the data stream of the LIGO detector which could contain only detector noise or signals in the noise. With this in mind, we train a binary classificator able to distinguish when in the data is present a merger. We create two distinguished datasets, one with the noise of the LIGO detector and one, following the data pre-processing of GW data, whitened with respect to the detector PSD. With two datasets, differing in the kind of detector noise, with the same amount of strains with signals in the noise and noise only, we obtain higher overall accuracy with the whitened dataset and more specifically for spectrograms. This representation performs more than 90 correct classifications.

Fourier transforms show similar behavior in both colored and whitened datasets with an accuracy of ~ 77%. Whitened time strains have a substantial increase in accuracy from the colored to the whitened dataset, respectively 50% and 73%. CNN trained on spectrograms correctly classify 93% of an external validation dataset demonstrating to be the representation with the highest accuracy on a BNS waveforms dataset, better than time series and FFT.

KEYWORDS CNN, gravitational waves

Features Selection and Imbalance Learning in Automatic Variable Star Classification

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In recent years, the amount of data in Astronomy has increased exponentially. In big surveys, classification of astronomical objects by eyes has become impractical. Machine Learning based classification is now a more preferable choice in astronomical data classification. One of the astronomical objects often studied in big surveys is the variable star. To classify different types of variable stars, ones need to first extract their light curve features. The number of extracted features can be quite big and some features might not be as useful as the others. Reducing the number of input variables can reduce the computational time and \textit{generally} improve the performance of the model.

Another problem usually encountered in variable star classification is the imbalance of data. In most surveys, the amount of non-variable stars far exceeds those of variable stars. The numbers of different types of variable stars also often vary greatly. Since most machine learning algorithms assume equal misclassification costs for all classes, the algorithms tend to be biased towards the majority class while the predictive performance of the minority class, which is usually of greater importance, could be compromised.

In this work, we not only aim to find an objective way to determine the optimal set of features by exploring different feature selection techniques but also to compare different imbalance learning techniques for variable star classification. Data used in this study is retrieved from the ASAS-SN archive. The results of this study can also be applied to other similar settings.

KEYWORDS Variable stars, Machine Learning, Classification

IAUS 368

#1043

Stellar Population Photometric Synthesis with AI of S-PLUS galaxies

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We trained a Neural Network that can obtain selected STARLIGHT parameters directly from S-PLUS photometry. The training set consisted of over 55 thousand galaxies with their stellar population parameters obtained from a STARLIGHT application by Cid Fernandes et al. (2005). These galaxies were crossmatched with the S-PLUS iDR 3 database, thus, recovering the photometry for the 12 band filters for 55803 objects. We also considered the spectroscopic redshift for each object which was obtained from the SDSS. Finally, we trained a fully connected Neural Network with the 12-band photometry + redshift as features, and targeted some of the STARLIGHT parameters, such as stellar mass and mean stellar age. The model performed very well for some parameters, for example, the stellar mass, with an error of 0.23 dex. In the future, we aim to apply the model to all S-PLUS galaxies, obtaining never-before-seen photometric synthesis for most objects in the catalogue.

KEYWORDS galaxies, stellar populations, machine learning, deep learning, artificial intelligence

IAUS 368
#998

Computational techniques for high energy astrophysics and medical image processing

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Ecuador, a Latinamerican country located at zero latitude, has an advantage to study high energy astrophysics due to its geography. Highlands in the Andes reach altitudes over the 5000 m.a.s.l. with no extreme climate conditions. The study of high energy astrophysics involves sophisticated computational techniques which are natural for medical image processing techniques. We present two studies where astrophysics and computational techniques are applied to astroparticle physics and medical image processing.

The first one is the use of software as Corsika, Gammapy, Astropy and ARTI to identify potential sites to study astroparticles physics in Ecuador. We determine the secondary particle fluence and M1 signal at different locations, and we calculated the effective area of a prototype Water Cherenkov Detector (WCD) in Quito.

The second work is the manipulation of medical images using python and PyDICOM libraries. Aiming to explore the Computer Aided Detection (CAD) systems for the automated detection of numerous lung diseases. We develop a tool for extracting information from DICOM files in an easy and fast way without needing to use other types of external programs, but only by using Python and the Jupyter Notebook. A second tool consists of a lung segmentation technique for computed tomography images. The segmentation process uses the pixel matrix in Hounsfield units to initially identify lung tissue through its degree of linear X-ray attenuation. Then, the marker-based Watershed algorithm is used, which is the main basis of the technique. In addition, different morphological operations and transformations are used on the axial sections for obtaining the lung segmentation.

This work shows the versatility of computational skills of astronomy to explore other fields and encourage students of scientific careers as physics to learn astronomy and programming.

KEYWORDS Corsika, gammapy, astropy, pydicom, astroparticles, Computer Aided Detection

IAUS 368
#912

Applied Machine Learning Models for Identifying Spectral Sub-Types of M Dwarfs from Photometric Surveys

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M dwarfs are the most abundant stars in the Solar Neighborhood and prime targets for searching for rocky-planets in habitable zones. Detailed characterization of these stars is highly demanded. The spectral sub-type of star is traditionally derived from observed stellar spectra. However, obtaining spectra of M dwarfs is expensive in terms of observing time and resources due to their intrinsic faintness. We study the performance of various machine learning models including K-Nearest Neighbor (KNN), Random Forest (RF), Probabilistic Random Forest (PRF), and Multilayer Perceptron (MLP) used to identify the spectral sub-types of M dwarfs at a grand scale by deploying solely the available broad-band photometry in the optical and Near-Infrared (NIR) of the interested stars as much as possible. We trained the machine learning models by using tens of thousands of spectroscopically identified M dwarfs from the Sloan Digital Sky Survey (SDSS) Data Release (DR) 7 together with the photometric colors derived from the SDSS, Two-Micron All-Sky Survey (2MASS) and Wide-field Infrared Survey Satellite (WISE). We found that the RF, PRF, and MLP have a comparable performance with the identification accuracy of 70%, which is significantly better than that of the KNN. When using RF and PRF, the most useful features are r-z, r-i, g-z, r-J, and i-z while including the other features improves the performance by only 1%. Our work will be useful for selecting stars for upcoming astronomical surveys and for studying and constraining the dependency of physical properties on stellar spectral sub-type.

KEYWORDS machine learning, M dwarfs, photometry, spectroscopy, exoplanet

IAUS 368

#888

Astronomical objects classification based on the Digitized First Byurakan Survey low-dispersion spectra

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The Digitized First Byurakan Survey is the largest and the first systematic objective-prism survey of the extragalactic sky. The detection, extraction, and classification of about 40 million spectra of about 20 million astronomical objects available in the survey require distinguishing the pixels containing photons from the source and the noise pixels per object. This work aims at developing a service to classify the spectra of UV-excess galaxies, quasars, compact galaxies, and other objects in the survey. Supervised and unsupervised convolutional neural network deep learning algorithms have been developed and studied.

KEYWORDS Astronomical data, DFBS, Machine learning, Data classification, Virtual Observatories, ArVO

IAUS 368

#760

Predicting Physical Parameters of Cepheid and RR Lyrae variables in an Instant with Machine Learning

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We present a machine learning method to estimate the physical parameters of classical pulsating stars such as RR Lyrae and Cepheid variables based on an automated comparison of their theoretical and observed light curve structure at multiple wavelengths. The period of pulsation and the structure of the light curve for Cepheid and RR Lyrae variables depend on the fundamental parameters of the star: mass, radius, luminosity, and effective temperature. We train artificial neural networks on theoretical pulsation models to predict the fundamental parameters of these stars based on their period and light-curve structure. We find significant improvements to estimates of these parameters made using light-curve structure and period over estimates made using only the period. Given that the models are able to reproduce most observables, we find that the fundamental parameters of these stars can be estimated up to 60 percent more accurately when the light-curve structure is taken into consideration. We quantify which aspects of light-curve structure are most important in determining fundamental parameters, and find, for example, that the second Fourier amplitude component of RR Lyrae light curves is even more important than the period in determining the effective temperature of the star. We apply this analysis to observations of hundreds of Cepheids in the Large Magellanic Cloud and thousands of RR Lyrae in the Magellanic Clouds and Galactic bulge to produce catalogs of estimated masses, radii, luminosities, and other parameters of these stars.

KEYWORDS Variable stars, RR Lyrae, Cepheid, machine learning, artificial neural networks

Neural Networks for Meteorite and Meteor Recognition

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In this paper, we present a convolutional neural network (CNN)-based architecture trained on a dataset of meteorites and terrestrial rocks and another dataset trained on meteors and light sources. For meteorites, the dataset comprises augmented images from the meteorite collection at the Sharjah Academy for Astronomy, Space Sciences, and Technology (SAASST). For meteors, the images are taken from the United Arab Emirates (UAE) Meteor Monitoring Network (MMN). Such a project's significance is to expand machine learning applications in astronomy to include the solar system's small bodies upon contact with the Earth's atmosphere. This, in return, acts as deep learning research, which examines a computer's ability to mimic a human's brain in recognizing meteorites from rocks, and meteors from airplanes and other noise sources. When testing the CNN models, results have shown that both the meteorite and meteor models reached an accuracy of above 80%.

KEYWORDS Machine learning, Convolutional Neural Networks, Meteorites, Meteors

IAUS 368

#670

KPSFinder: a machine learning-based exoplanet searching tool

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One of the best and most direct ways to study planet formation processes is to observe young planets while they are forming within their birth protoplanetary disks. As they form, planets tidally interact with their parental disk and produce observable signatures. Recent observations have demonstrated that kinematic planetary signatures (KPS), the perturbed velocity fields of the gas in the protoplanetary disk in the vicinity of the planet, can be observed with the Atacama Large Millimeter/submillimeter Array (ALMA). Until now, searching for KPS in ALMA data has been relying on visual inspection. While this has been successful for a few of the most straightforward cases, many candidates remain inconclusive. Furthermore, in order to estimate the mass of the planet associated with the KPS, one has to carry out multiple three-dimensional planet-disk interaction simulations, post-process the simulation outputs by running radiative transfer calculations, and make a thorough comparison between the simulated data and the observational data, which are very time-consuming. In this poster, I will introduce a machine learning-based exoplanet searching tool KPSFinder (Kinematic Planetary Signature Finder). KPSFinder is trained with synthetic molecular line cubes adopting convolutional neural networks. With the trained model in hand, users will be able to check whether their data cube contains KPS, localize the KPS within the disk, and estimate the mass of the planet driving the KPS, within a few minutes using a single CPU core on a personal computer.

KEYWORDS machine learning, protoplanetary disks, exoplanets

IAUS 368
#557

Deep Learning-based Search for Lensed Gravitational-Wave Signals from Binary Black Hole Events in GWTC-1 and -2

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We present the result of a deep learning-based search for beating patterns, one of the gravitational lensing signatures, from the observed gravitational-wave signals. In this search, we examine the binary black hole events in the first and second gravitational-wave transient catalogs. This search is the first endeavor utilizing deep learning for searching lensing signatures from gravitational waves. Specifically, the search identifies beating patterns induced by lenses with masses between 103--105M_sun from spectrograms of gravitational-wave signals. We train a deep learning model with spectrograms of simulated noisy gravitational-wave signals to classify the binary black hole events into two classes, lensed or unlensed signals. We introduce an ensemble learning with the deep learning model and employ a majority voting strategy for the predictions of all ensemble learners. From the majority voting-based primary classification, we find that one event out of forty-six events is classified as lensed. We validate the lensed event by estimating its p-value and identify that the p-value is ~= 0.0025 which is higher than an expected value (<< 0.001) for claiming strong evidence of lensing. Therefore we conclude all binary black hole events evaluated by the deep learning model are unlensed.

KEYWORDS Gravitational waves, Strong gravitational lensing, Astronomy data analysis, Convolutional neural networks

IAUS 368

#334

Bayesian vs frequentist: comparing Bayesian model selection with a frequentist approach using the iterative smoothing method

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We have developed a frequentist approach for model selection which determines the consistency between any cosmological model and the data using the distribution of likelihoods from the iterative smoothing method. Using this approach, we have shown how confidently we can conclude whether the data support any given model without comparison to a different one. In this current work, we compare our approach with the conventional Bayesian approach based on the estimation of the Bayesian evidence using nested sampling. We use simulated future Roman (formerly WFIRST)-like type Ia supernovae data in our analysis. We discuss the limits of the Bayesian approach for model selection and show how our proposed frequentist approach can perform better in the falsification of individual models. Namely, if the true model is among the candidates being tested in the Bayesian approach, that approach can select the correct model. If all of the options are false, then the Bayesian approach will select merely the least incorrect one. Our approach is designed for such a case and we can conclude that all of the models are false.

KEYWORDS Bayesian reasoning, Frequentist statistics, dark energy experiments, supernova type Ia - standard candles

IAUS 368
#3322

Forecasting SN explosions Using Deep Learning toward High-Resolution Galaxy Simulations

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Small integration timesteps for a small fraction of short-timescale regions become a bottleneck for galaxy simulations with a higher resolution, especially when using massively parallel computing because they worsen the scalability. For future higher-resolution galaxy simulations, we need to overcome this problem. The regions affected by a supernova (SN) often have the smallest timestep in galaxy simulations. We, therefore, adopt a Hamiltonian splitting method, in which SN regions are integrated with small timesteps using a lower number of CPUs, but the entire galaxy is integrated with a shared timestep (global timestep) using massively parallel CPUs. We are implementing such a Hamiltonian splitting method in our smoothed-particle hydrodynamics (SPH) code. This approach needs to pick up particles in regions affected by SN explosions (the target particles) by the subsequent global step in advance.

In this work, we present a deep learning model to predict the region where the shell due to an SN explosion expands during one global step. We develop the deep learning model based on Memory In Memory (Wang et al. 2018), which predicts subsequent videos from previous frames. We expand the dimension of the model's tensors and I/O mechanisms from two to three dimensions (3D) to learn and forecast the time series of distributions of physical quantities in 3D simulations. We also modify the model to forecast the expansion of SN shells using only one frame (distribution of gas) just before the explosion, although the original model forecasts subsequent frames using a few frames. In addition, we develop an algorithm to identify the target particles using image processing of the density distribution predicted by the deep learning model. The algorithm can identify the target particles better than the method based on an analytic solution. This work demonstrates the possibility of achieving high parallelization efficiency on state-of-the-art supercomputers such as Frontier and Fugaku.

KEYWORDS methods: numerical

IAUS 368
#3108

Machine Learning in Photometric Redshifts: The Performance of ANNz After 18 Years

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Artificial Neural Network Redshift (ANNz) introduced by Collister and Lahav (2004) was among the first machine learning photometric redshift algorithms that existed and was widely used by many. Notably, it is fast, simple and lightweight as compared to many other algorithms. As the technology and theory of artificial neural networks have progressed tremendously since then, it begs the question to see if ANNz remains competitive 18 years after its debut. In this work, we made simple modifications on ANNz, focusing on introducing newer and more modern activation functions such as the hyperbolic tangent (tanh), softplus, swish and ReLU, then compare their performances to its original algorithm which uses the classic logistic sigmoid activation function. The updated algorithm was tested on classic galaxy samples like the Main Galaxy Sample, Stripe-82 Survey, and also on newer galaxy data like those from the Physics of the Accelerating Universe Survey (PAUS). We tested many different architectures that vary in depth and breadth to gain an insight on how the activation functions react to the data. In general, our results showed that ReLU and tanh are more competitive and stable across the deeper and broader architecture with approximately >1% improvement of the RMS error (σRMS) and 68th percentile error (σ68) of the photometric redshift for a low-redshift galaxy sample. We also find that with appropriate optimisation on the updated algorithm, an improvement of 11% in σRMS and 6% in σ68 can be seen when applied to PAUS, a 40-narrowband survey. With appropriate architecture and on certain data sets, ANNz could even outperform ANNz2, its successor, an improvement as high as 19%. All these results imply that with appropriate modifications, ANNz would still remain competitive on the photometric redshift market, and with newer and higher quality photometric data constantly incoming, it remains to be seen how the trajectory of performance for machine learning photometric redshift algorithms will go.

KEYWORDS photometric redshift, artificial neural network, ANNz, galaxy, distance and redshift

IAUS 368
#2299

Assessing the quality of massive spectroscopic surveys with unsupervised machine learning

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Massive spectroscopic surveys targeting tens of millions of stars and galaxies are starting to dominate the observational landscape in the 2020 decade. For instance, a night of observation with the Dark Energy Spectroscopic Instrument (DESI) can measure on the order of 100k spectra, each spectrum sampled over 2k wavelength points, approximately. Assessing the quality of such a massive data flow requires new approaches to complement visual inspection by humans. In this work, we explore the Uniform Manifold Approximation and Projection (UMAP) as a technique to assess the data quality of DESI. We use UMAP to project DESI nightly data into a 2-dimensional space. Sometimes in this space, we are able to find a small number of outliers. After visual inspection of those outliers, we find that they correspond to instrument fluctuations that can be then fully diagnosed by inspecting the raw data, allowing the development of an appropriate solution through data re-processing. These results pave the way for to use machine learning techniques to automatically monitor the health of massive spectroscopic surveys.

KEYWORDS Massive spectroscopic data, Unsupervised Learning

IAUS 368

#2859

Deep learning likelihood-free inference of Star Formation and Accretion Histories of galaxies

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Galaxies grow via star formation and by accreting stars from other galaxies. The relative contribution of these two physical process over cosmic time is still unconstrained. I this work, we present a deep probabilsitc learning approach to infer Star Formation Histories and Accretion Histories of large volumes galaxies in order to contstrain their formation histories.

1. I will first illustrate a new method based on deep probabilistic generative neural network models to recover posterior distributions of the star formation histories of galaxies. The model is trained on mock photometry from cosmological simulations (EAGLE and TNG) from which it learns a prior of the SFHs. By training and testing on different simulations we show that the model is able to generalize across simulations with different physical models. In particular we show that the estimated SFHs properly capture bursts and drops in the star formation rate even at very high redshift.

2. We then attempt to infer the stellar assembly of galaxies utilizing solely two-dimensional maps of mass, stellar velocity and velocity dispersion. We show that the fraction of stars formed outsied the galaxy can be inferred with high accuracy when the deep learning models are trained on simulation data using the mass and kinematic maps.

By combining these two approaches, we are able to reconstruct the two channels of galaxy growth based on current observables for large samples of galaxies.

KEYWORDS likelihood free inference, galaxy evolution

IAUS 368
#2767

Spectral Identification and Classification of Dusty Stellar Sources Using Spectroscopic and Multiwavelength Observations Through Machine Learning

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Surveys have acquired large datasets over the multiwavelength sky. Data acquisition and analysis have contributed significantly to the understanding of dusty stellar sources, for instance, the YSOs and evolved stars. Indeed, the growing number of spectroscopic observations and confirmed stellar spectra has necessitated the development of novel approaches for identifying and classifying stellar sources. As a result, machine learning enhances the accuracy of spectral classification of dusty point sources while also validating candidate spectroscopic catalogs and identifying unclassified spectra. We propose a machine learning approach to identify and distinguish dusty stellar sources employing supervised and unsupervised methods and categorizing point sources, mainly evolved stars, using photometric and spectroscopic data collected over the IR sky. Spectroscopic data is typically used to identify specific infrared sources. However, our goal is to determine how well these sources can be identified using multiwavelength data. Consequently, we developed a robust training set of spectra of confirmed sources from the Large Magellanic Clouds SAGE-Spec Spitzer and the Small Magellanic Clouds Spitzer Infrared Spectrograph. Subsequently, we applied various learning classifiers, consisting of Decision tree (DTC), Gradient Descent, Support-Vector Machine, KNearest Neighbor (KNN), Linear Discriminant Analysis (LDA) to distinguish five stellar subcategories comprising Young stellar objects (YSOs), C-rich AGB star (CAGB), O-rich AGB star (OAGB), Red supergiant (RSG), and post-AGB star. We have classified around 700 counts of these sources. The accuracy of the findings of three models, namely KNN, DTC, and LDA, was around 89 percent, which is remarkable for such a limited number of spectral counts. Following that, we augmented the data for the DTC classifier. Accordingly, the accuracy of the DTC model increased from 86 percent to 92 percent. It should be highlighted that, despite utilizing the limited set of spectroscopic data that we trained, the learning curve of our models provides outstanding results. To further investigate, Our machine learning models for categorizing dusty stars can improve by employing data augmentation and expanding spectroscopic data and approved catalogs, including the JWST.

KEYWORDS stellar classification, machine learning, spectroscopic catalogs, multiwavelength observation, SAGE-Spec, dust, LMC and SMC

IAUS 368

#2728

Machine Learning projects within the BlackGEM collaboration

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BlackGEM is a wide-field telescope array dedicated to measure the optical emission from pairs of merging neutron stars and black holes, and its operations will be triggered by the Advanced LIGO & Virgo gravitational wave detectors. The three 65-cm telescopes installed in La Silla are currently undergoing commissioning in April 2022. In addition, the prototype system MeerLICHT was installed in July 2017 and has remained operational at the SAAO Sutherland site in South Africa since then. The operation of MeerLICHT has already allowed us to collect time-domain data on a large portion of the Southern sky, mainly in the u, q (broad-band), and i-bands. In my talk, I will briefly present the BlackGEM survey and describe the ongoing machine learning projects within the collaboration, which include real/bogus classification (MeerCRAB; Hosenie et al. 2021), source detection in crowded fields (AutoSourceID-Light; Stoppa et al. 2022), and light curve classification among others. I will put special attention to the challenges of each project, and present the first results and future steps.

KEYWORDS machine learning, time-domain, survey, optical, transients

IAUS 368

#2486

Emission-line diagnostics of HII regions using conditional Invertible Neural Networks

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The stellar feedback is an energetic interaction between star clusters and the surrounding interstellar medium (ISM) that self-regulates the star formation in giant molecular clouds. Studying stellar feedback generally relies on observations of star-forming regions but inferring the physical properties from photometric and spectroscopic measurements is difficult because observational data are highly degenerate due to the complexity and non-linearity of stellar feedback.

On this account, we introduce a novel method that couples a conditional invertible neural network (cINN) with the WARPFIELD-emission predictor (WARPFIELD-EMP) to estimate the physical properties of star-forming regions from spectral observations (Kang et al. 2022). We present a cINN that predicts seven physical parameters (cloud mass, star formation efficiency, cloud density, cloud age which means age of the first generation stars, age of the youngest cluster, the number of clusters, and the evolutionary phase of the cloud) from the luminosity of 12 optical emission lines within the range from 3700 to 9600Å, and test our network with synthetic models that are not used during training. Our network is a powerful tool that provides accurate and precise posterior distributions for each parameter, although degeneracy sometimes remains in the posterior estimates of the number of clusters. We validate the posteriors estimated by the network and confirm that they are consistent with the input observations. We also introduce a method to obtain a posterior distribution considering observational uncertainties and evaluate the influence of uncertainties on network performance.

Our network is a time-efficient tool that can analyze a large number of observations in a short time so it is applicable to various survey data. We are planning to apply our network to the forthcoming SDSS-V LVM survey and also to the PHANGS-MUSE survey of HII regions in nearby spiral galaxies.

KEYWORDS HII regions, star formation, ISM

IAUS 368
#2378

On the Distribution of Bayesian Evidences

Ryan Keeley[1]

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In this talk, I discuss the distribution of the Bayesian evidence for mock realizations of supernova and baryon acoustic oscillation data. The ratios of Bayesian evidences of different models are often used to perform model selection. The significance of these Bayes factors are then interpreted using scales such as the Jeffreys or Kass \& Raftery scale. First, I show how to use the evidence itself to validate the model, that is to say how well a model fits the data, regardless of how well other models perform. The basic idea is that if, for some real dataset a model's evidence lies outside the distribution of evidences that result when the same fiducial model that generates the datasets is used for the analysis, then the model in question is robustly ruled out. Further, I will discuss how to assess the significance of a hypothetically computed Bayes factor. I will demonstrate that the range of the distribution of Bayes factors can greatly depend on the models in question and also the number of independent degrees of freedom in the dataset. Thus, I will argue that the significance of Bayes factors needs to be calculated for each unique dataset.

KEYWORDS Statistics, Cosmology

IAUS 368
#2143

Dissecting quasars with microlensing in the era of LSST

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Despite the discovery of quasars almost 60 years ago, the detailed mechanism of mass accretion that powers them has remained largely unknown. This process has far-reaching effects in many fields of astrophysics but operates at spatial scales far too small to be resolved by any current or foreseeable telescope. However, nature has given us a powerful tool to dissect quasar interiors: gravitational microlensing, the effect of stars within galaxies acting as strong gravitational lenses on distant quasars. In particular, it is the rare, 1-per-decade High Magnification Events that are sought-after, which are caused when the quasar accretion disc crosses a microcaustic and usually last from a few days to weeks. If observed in many wavelengths, from optical to X-rays, they can provide crucial information on the structure of the accretion disc and the supermassive black hole that sustains in. But in order to trigger such expensive multi-wavelength follow-up, these events need to be predicted in advance, something achievable only if several thousands of lensed quasars are monitored on a weekly basis for a decade or longer. The upcoming LSST survey is ideal for this task and its 6-band light curves will provide a massive dataset to mine and use to predict the onset of high magnification events. I will present two parallel machine learning approaches that are both trained on state-of-the-art microlensing simulations and applied to simulated LSST and existing COSMOGRAIL light curves, respectively. These first attempts have provided quite encouraging results for tackling the problem in its entirety, which entails: 1) addressing the variety of the underlying physical system, e.g. different accretion disc and microlensing models, and 2) imperfect data (sparse, irregular sampling, etc) and data pre-processing (e.g. little-known time delays). Finally, I will discuss the prospect of evolving these methods into a robust microlensing alert system integrated in LSST.

KEYWORDS accretion, accretion discs, gravitational lensing: micro, quasars:general

IAUS 368
#1819

ML in trigger schemes for time-domain studies

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Many time-domain studies rely on simultanous observations conducted in different frequency regimes. Observations with one facility triggers observations with other instruments. Beyond the need to provide clean stes of triggers with small numbers of false positives, a characterisation of triggers that predict the properties of multifrequency counterparts is desirable in optimizing success rates in multifrequency monitoring.

We describe a series of simple analytic generic preditction schemes and compare their success rates to predictions provided from ML_based prediction schemes, trained with real data. We apply the method to different targets in gamma-ray astronomy. In this presentation we describe an example predicting flare-amplitudes and flare shapes of variable AGN and Gamma-Ray Busrst in different frequeny regimes - based on ML-trained networks using archival data obtained with identical instrumental set-up. We compare and discuss success rates of different schemes and attempts of characterizing the performance of sufferenet schemes in multidimensional parameter sets.

KEYWORDS multiwavelength, variability, trigger, ML, statistical properties

Machine learning as a tool for discovery in X-ray datasets: time-domain and beyond

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The field of time-domain astronomy at X-ray energies is promising. The eROSITA telescope will scan the entire X-ray sky once every half a year, resulting in multiple visits of any part of the sky during its first 4 years of operation, probing variability timescales ranging from seconds to years, with the first data release already available to the community. Athena, which will provide hybrid capabilities between the sensitivity of Chandra and the area coverage of eROSITA, and Lynx, with an improved sensitivity and resolution with respect to Chandra, will both provide rich time-domain datasets. Because of their volume and complexity, high energy datasets such as the Chandra Archive have become recent targets of data science and machine learning algorithms, leading to new and exciting discoveries. Largely unexplored, Chandra archival data offers an excellent testing ground (as well as a fertile ground for discovery) for novel techniques of classification, and for transient and anomaly detection. Using the Chandra archival data as a study case, we present examples of how treating X-ray datasets from a machine learning perspective can enhance their scientific value. We focus on three general ideas: 1) unsupervised machine learning can be an effective way to classify X-ray sources when robust training sets cannot be constructed, even on the absence of optical/IR counterparts; 2) Transients can be searched for systematically using properties derived from X-ray light curves; and 3) Variability and spectral properties can be learned directly from event lists using appropriate embeddings and neural network architectures. We highlight some findings that this data science perspective has allowed in Chandra data, and provide some recipes to easily access high energy datasets.

KEYWORDS Machine Learning, X-ray datasets, High energy astrophysics, Anomaly detection, Time domain astronomy, Classification, Neural networks

IAUS 368

#1709

Interpreting machine learning models: A case of star-quasar-galaxy classification in large-sky surveys

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I will present a study published in the Monthly Notices of the Royal Astronomical Society as the first author (Nakazono et al. 2021), where we detail a supervised learning approach to perform a star-quasar-galaxy classification for a photometric large-sky survey named Southern Photometric Local Universe Survey (S-PLUS). Using spectroscopically confirmed sources from the Sloan Digital Sky Survey, we show that Random Forest is faster and achieves better performance than Support Vector Machines, by comparing the macro-averaged F-measure (as this one is best for unbalanced dataset). We have chosen these two algorithms as both are non-parametric models and therefore require fewer assumptions about the data distribution. All comparisons were done within a 5-fold cross-validation with stratified splitting considering magnitudes and morphological parameters from S-PLUS and magnitudes from Wide-field Infrared Survey Explorer (WISE). We achieve 95.76% (52.47%) of quasar purity, 95.88% (92.24%) of quasar completeness, 99.44% (98.17%) of star purity, 98.22% (78.56%) of star completeness, 98.04% (81.39%) of galaxy purity, and 98.8% (85.37%) of galaxy completeness with Random Forest and considering a test sample containing only objects with (without) WISE counterpart. We also obtain a better performance than a self-supervised deep learning classifier (Martinazzo, Espadoto & Hirata, 2020), for which they obtain an accuracy of 88.28% within a balanced dataset of S-PLUS objects that have a WISE counterpart. As the S-PLUS optical filter system consists of 5 Sloan-like and 7 narrow bands centered on stellar features, it is important to evaluate how useful the narrow bands are for the classification task. We were able to statistically show, using Wilcoxon signed-rank test with a confidence level of 90%, that training a classifier with narrow-band magnitudes provides better performance than training solely with broad bands, regardless of infrared information inclusion. We also show in this work that our classifiers are robust against missing-band values, which is important in order to avoid our model being biased towards bright objects. In this talk, I would like to show how we build our strategy to get to interpret our machine learning results while focusing on the best practices.

KEYWORDS quasar, narrow-band survey, classification, random forest, machine learning, statistics

IAUS 368
#1429

Making Unexpected Time-domain Discoveries in Astronomy with Machine Learning

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How to search for the unexpected if we don't know what we are looking for? These objects often lead to new breakthroughs, yet most discoveries are found serendipitously. Current traditional search algorithms are also catered to find what we have already known. Though large amounts of astronomical data are available, they are unlabelled and would be impractical for manual inspection. Anomaly detection for machine learning offers a way to search and automate the process of detecting anomalies or novelties. I will present a curated dataset for finding the unexpected with the Murriyang (Parkes) radio telescope. I will discuss the effectiveness and limitations of anomaly detection machine learning methods against traditional searches in making time-domain discoveries.

KEYWORDS anomaly detection, machine learning, time-domain, radio dataset, transients, extraterrestrial intelligence, radio sources

IAUS 368

#1332

New types of periodograms based on phase distance correlation

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We present a novel approach to the detection of periodicity, which is based on the concept of Distance Correlation. Distance Correlation is a recently introduced test for statistical dependence. Periodicity can be defined as dependence on the phase, determined according to some period. The novel approach uses distance correlation to quantify and search for this dependence. Since distance correlation can be defined on various metric spaces, it can be used to search for many types of periodic dependence, rather than only for simple scalars (like brightness or radial velocities) - it can be used also to search for astrometric periodicity or even spectral-shape periodicity.

KEYWORDS period detection, statistical dependence, periodogram, statistical methods

IAUS 368
#1118

A Deep Learning approach to Large Scale Structure Cosmology

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I will review the current status of machine learning as it is applied to the large scale structures in the Universe. Galaxy surveys, weak gravitational lensing, 21cm intensity radio projects and the CMB are providing us with maps of the large scale structures in the Universe. These maps are typically analysed with tried and tested statistical techniques such as correlation functions and power spectra, which can relate observation to a theoretical model. However, recently there has been many works exploring the use of machine learning methods to extract cosmological physics from astronomical data. In this talk I will show a few examples of these works and give a more detailed exposition using my own recent work on probing the nature of dark matter using 21cm tomography with convolutional neural networks (arxiv:2108.07972).

KEYWORDS deep learning, cosmology, large scale structure, dark matter

IAUS 368
#890

Photometric redshifts for the S-PLUS survey: is machine learning up to the task?

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Redshifts, and consequently distances, are fundamental quantities to several studies in astronomy, ranging from the understanding of galaxy formation and evolution in different environments to the identification of clusters of galaxies. Although important, it is very difficult, if not impossible, to obtain this quantity spectroscopically for the newest generation of all-sky surveys, which will observe millions or billions of objects. A second approach, then, must be used. Using a photometric filter system and template fitting or machine learning techniques, we are able to estimate a photometric redshift, which has a lower accuracy but can be obtained for all objects in a survey in a very time-efficient manner. In this talk I will present about our most recent results obtained with a Bayesian Mixture Density Network model, which is trained using information from the Southern Photometric Local Universe Survey (S-PLUS), complemented with GALEX and unWISE magnitudes, to estimate photometric redshifts. Using a set of tests, we verify that this model is able to recover accurate single-point estimates and well-calibrated probability distribution functions for galaxies with r-band magnitudes between 16 and 21. The catalogue with single-point photometric redshifts and probability distribution functions is now publicly available at https://splus.cloud/. We expect this work to be useful in several studies for the public and in our collaboration. Also, future work will develop upon this tool to study the large scale structure of the local Universe.

KEYWORDS galaxies, distances, photometric, survey, deep learning

Machine-assisted Exploration of Simulation Parameters

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[3]*Physics and Astronomy, Korea Astronomy and Space Science Institute, Republic of Korea*

Numerical simulation is a key component used to study the formation and evolution of large-scale structures in the universe. The predictive capability of the simulations is realized when they are calibrated to match observations. However, it is near impossible to fully explore the parameter space of a numerical simulation. In this talk, I will present a novel method of using machine learning to obtain a set of parameters that produces a simulated galaxy matching observed properties at z=0. I will discuss the improvements in the accuracy of the results and demand in computational resources with this approach. Also, I will demonstrate the robustness of the algorithm by applying it to a different problem faced in numerical simulations.

KEYWORDS Numerical simulatons, Machine learning, Galaxy evolution

IAUS 368
#720

The information content of galaxy spectra

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Galaxy spectra encode a large amount of information regarding the underlying stellar populations that reflect the past star formation and chemical enrichment history. Traditional approaches based on comparisons with population synthesis models are adopted to constrain the stellar ages and chemical composition. However, the results are hampered by the notorious age-metallicity-dust degeneracy. Machine Learning methods rely instead on the statistical trends found in the data, although the latest state-of-the-art results can only provide rather simplistic classifications, mostly separating 'blue' and 'red' galaxies. In this contribution, we explore this problem from an information theory approach, defining the entropy of galaxy spectra and comparing samples of real galaxies with synthetic models. Information theory allows us to understand at a more fundamental level the problems that any sophisticated ML method will encounter, and can help to find new ways to tackle this difficult problem.

KEYWORDS galaxy formation, population synthesis, data analysis, galaxy evolution, spectroscopy

Revealing the Local Cosmic Web from Galaxies by Deep Learning

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A total of 80% of the matter in the universe is in the form of dark matter that composes the skeleton of the large-scale structure called the cosmic web. As the cosmic web dictates the motion of all matter in galaxies and intergalactic media through gravity, knowing the distribution of dark matter is essential for studying the large-scale structure. However, the cosmic web's detailed structure is unknown because it is dominated by dark matter and warm-hot intergalactic media, both of which are hard to trace. Here we show that we can reconstruct the cosmic web from the galaxy distribution using the convolutional-neural-network-based deep-learning algorithm. We find the mapping between the position and velocity of galaxies and the cosmic web using the results of the state-of-the-art cosmological galaxy simulations of Illustris-TNG. We confirm the mapping by applying it to the EAGLE simulation. Finally, using the local galaxy sample from Cosmicflows-3, we find the dark matter map in the local universe. We anticipate that the local dark matter map will illuminate the studies of the nature of dark matter and the formation and evolution of the Local Group. High-resolution simulations and precise distance measurements to local galaxies will improve the accuracy of the dark matter map

KEYWORDS cosmology, dark matter, large-scale structure of the universe, Local Group, artificial intelligence

IAUS 368

#558

The faint end of the quasar luminosity function at z~5 based on deep learning and Bayesian statistics

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The faint end of the quasar luminosity function at z~5 is highly uncertain due to insufficient data points in the faint end and their large uncertainties. In this study, we gave an effort to extend the faint end of the quasar UV luminosity function by using a source catalog from the Hyper Suprime-Cam Subaru Strategic Program (HSC-SSP) reaching r ~ 27 AB mag and adopting deep learning and Bayesian statistics as an alternative selection process to conventional color selection. Deep learning enabled us to find quasars at z=4.5 – 5.5 among non-quasar objects, maximizing the recovery rate of quasars. Bayesian information criterion could choose promising candidates by comparing their SEDs to star and quasar model SEDs. As a result, we can obtain the deepest quasar UV luminosity function reaching down to M_{1450} ~-22.0 mag, which is ~ 1 mag deeper than previous researches. The derived faint-end slope is -1.6_{-0.19}^{+0.21}, which is the most reliable estimate compared to other slopes calculated from the fixed bright-end slope or small sample size. 5/6 spectroscopically confirmed quasars are recovered via our selection, indicating ~ 80% quasar recovery rate. To assess the contamination rate of final candidates, we used 8 spectroscopically confirmed Lyman break galaxies at z~5, which are the most contaminant sources in the survey for faint quasars. The contamination rate of our selection is 1/8, which is three times lower than that of color selection (3/8). This might prove the efficiency of our selection in terms of quasar recovery rate and contamination rate.

KEYWORDS Quasar, Luminosity function, Deep learning, Bayesian information criterion, Survey

IAUS 368
#528

Machine Learning in the study of Star Clusters with Gaia EDR3

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Determination of membership of star clusters is a very important criterion in their study as they effect determination of cluster parameters like radius, age, distance, mass functions, etc. In an earlier study, we used published membership data of nine open star clusters as a training set to find new members from Gaia DR2 data using a supervised random forest model with a precision of around 90\%. The number of new members found is often double the published number. In this talk, I would like to compare the ealier results with results obtained by applying the unsupervised method of Gaussian Mixture Modelling (GMM) and Density-Based Spatial Clustering of Applications with Noise (DBScan) to study themembership of 9 open star clusters of varying ages and locations in the galaxy using Gaia DR2 and EDR3 data. We compare our results to help compare the efficiency of GMM and DBScan. We select stars from the Gaia-EDR3 catalog, and construct a five-dimensional phase space (three-dimensional spatial position and two-dimensional proper motion) and obtain reliable cluster members. We obtain cluster parameters for our sample using both methods and compare it with the catalog values. The technique demonstrates the effectiveness of machine learning in membership determination of clusters and focuses on the caveats involved.

KEYWORDS Machine Learning, Random Forest, GMM, DBScan, Gaia EDR3, Star Clusters

IAUS 368
#384

LSST AGN Data challenge – summary

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The active galactic nuclei (AGN) Data Challenge 2021 aims at developing data driven methods and models for AGN science with the Rubin Observatory Legacy Survey of Space and Time (LSST). Three main focuses are: parametrization of AGN light curves; AGN selection; determining AGN photometric redshift (photo-z). The datasets are pulled from different public archives and put together to mimic the future LSST data release catalogs as much as possible and follow the LSST Data Products documents (LSE-163). The objects included in the dataset are drawn from two survey fields, an extended Stripe 82 area and the XMM-LSS region. Objects are classified as stars, quasars/AGNs and galaxies. The total number of objects (both combined) in the Object table is ~440,000 and the total number of epochs is ~5M.

We used both supervised and unsupervised learning for star/galaxy/qso classification(clustering). For supervised learning, we used a simple artificial neural network (ANN), support vector machine (SVM), XGBoost (XGB) and random forest (RF). The comparison of performance of each method is a good starting point towards building more advanced models.

For supervised learning, we were able to achieve a high baseline accuracy for each method (accuracy>98%) when the light curve features are taken into account. The XGB and RF perform the best overall on this subset of data, which is very often the case for machine learning applications on tabular data. The performance rating measured by classification accuracy is XGB>RF>NN>SVM. Applying the same methods on the same set when the light curve features are removed, reduces the classification accuracy to ~94%

Unsupervised methods are usually statistically weaker and are in general outperformed by supervised methods on similar problems. We used deep embedding clustering (DEC), that is centered around building an autoencoder for dimensionality reduction and clustering using latent features in a similar fashion as t-SNE. We were able to reach ~97% clustering accuracy on the same dataset as methods listed above.

KEYWORDS

IAUS 369

The Dawn of Cosmology & Multi-Messenger Studies with Fast Radio Bursts

Invited & Contributed Talks

IAUS 369

#2678

Recent results from FRB surveys

Evan Keane[1]

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In this talk I will overview the abundance of results coming out of ongoing FRB surveys across the planet. The increasing yields of FRBs, and their ever more precisely measured properties, has shown a diversity in the underlying population. These gives clues as to the progenitors involved. In addition to the nature and behaviour of FRB-emitting sources, the surveys are enabling tests of fundamental physics. Half-way through the second decade of FRB science, we have now truly entered the dawn of FRB cosmology. I will overview what the survey results are telling us about the Universe, and what new investigations look set to be possible with FRBs in the coming years.

KEYWORDS

IAUS 369

#1820

Fast Radio Bursts with ASKAP - in 3 acts

Keith Bannister[1]

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The Australian Square Kilometer Array Pathfinder (ASKAP) is one of the leading fast radio burst detection and localisation telescopes. I will review some of the scientific highlights through the lens of three distinct observing phases: the fly's-eye wide-field mode, the incoherent sum mode, and a new coherent mode we are currently developing. Key among these highlights include the dispersion measure-fluence relation, first accurate localisation of a once-off FRB, constraints on the density and magnetisation of a galactic halo, and the first measurement of the dispersion measure - redshift relation, also known as the Macquart relation.

I will also describe the new CRAFT coherent upgrade (CRACO), which is currently being commissioned. This upgrade will form and search over 20 trilliion effective pixels per second, equivalnet to almost 1 milion uncompressed youtube videos.

KEYWORDS FRB, ASKAP, coherent

IAUS 369

#1552

Pinpointing FRBs in space and time: A study of localised FRBs from MeerTRAP

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Fast Radio Bursts (FRBs) are cosmological, radio flashes whose origins are still a mystery in spite of the significant progress made in the last 15 years. They are promising candidates to serve as independent probes of Cosmology. However, their true potential can only be realised by localising them and identifying their host galaxies. It is also important to study the host galaxies of well-localised FRBs along with the bursts themselves. Studying the host galaxy reveals crucial information about the environment of FRB progenitors and how it correlates with the various measured properties of the galaxy itself. To achieve this, significant effort is being put into localising FRBs to sub-arcsecond precision using radio interferometers around the globe. In this talk, I will report on the localisation and multi-wavelength follow-up effort with the MeerTRAP instrument deployed on the MeerKAT telescope in South Africa. I will briefly discuss our sample of well-localised FRBs and their host galaxy identifications and present the results of their spectroscopic follow-up. Furthermore, I will present the localisation and optical follow-up of an FRB localised to sub-arcsecond precision at z~1. Characterization of host galaxies at high redshifts has significant implications on the cosmological evolution of FRBs and their contribution to being precise probes of distant Cosmology.

KEYWORDS Transients, Fast Radio Bursts, Radio Astronomy, MeerKAT

IAUS 369
#1972

Pinpointing repeating FRBs with EVN-PRECISE

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The precise locations of FRB emitters within their host galaxies offer a powerful diagnostic to differentiate between source models. For example, the co-location with star-formation (or not) can differentiate between models that invoke young sources versus delayed formation channels. For relatively nearby sources, we can zoom in on their local environments using space-based optical observations (Hubble, JWST) and milliarcsecond localisations using radio VLBI. At these extreme levels of astrometric precision, one can quantify offsets with star formation in the host galaxy on the order of 10-100 pc, and compare with compact persistent radio emission on sub-parsec scales. In the future, the ELT may even allow us to associate FRBs with individual stellar companions in their host galaxies. I will present our latest results from the PRECISE project, in which we use an ad-hoc array of European VLBI Network (EVN) dishes to localise FRBs to milliarcsecond precision. With PRECISE, we have recently doubled the number of repeating FRBs that are localised to this precision. We have used this to pinpoint repeaters with respect to local star formation, in combination with Hubble observations, and have found that one nearby FRB is surprisingly located within a globular cluster in the M81 galactic system - thereby showing that it cannot be a young magnetar formed via core collapse of a massive star.

KEYWORDS Fast radio bursts, FRB, Transients, VLBI, Astrometry

IAUS 369

#2463

The short, high-DM FRB sky in sharp view

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Identifying the physical nature of Fast Radio Burst (FRB) emitters arguably requires good localisation of more detections, and broadband studies enabled by real-time alerting. I will present the results, and lessons learned, from the Apertif FRB survey (ALERT) that ran 2019-2022. ALERT was powered by the Apertif Radio Transient System (ARTS), a supercomputing radio-telescope instrument that performs real-time FRB detection and localisation on the Westerbork Synthesis Radio Telescope (WSRT) interferometer. It reaches coherent-addition sensitivity over the entire field of the view of the primary-dish beam. We detected a new FRBs every week of observing on average, and interferometrically localised these to ~0.4 - 10 sq.arcmin. I will present the first data release, and its interpretation. All detections contained in these data are broad band and very narrow, of order 1ms duration, and unscattered (although in later bursts, scattering is present, and well resolved). Dispersion measures are generally high. Only through the "sharp" -- very high time and frequency resolution -- view of ARTS are these hard-to-find FRBs detected, producing an unbiased view of the intrinsic population properties. I will next describe how the FRBPPOPPY population synthesis of these Apertif bursts compares against that based on the CHIME sample. Mean while, most Apertif localisation regions are small enough to rule out the presence of associated persistent radio sources. Three FRBs cut through the halos of M31 and M33. We demonstrate that Apertif can localise one-off FRBs with an accuracy that maps magneto-ionic material along well-defined lines of sight. The solid detection rate next ensures a considerable number of new sources are detected for such study. The combination of detection rate and localisation accuracy exemplified by these ARTS FRBs thus marks a new phase in which a growing number of bursts can be used to map out our Universe.

KEYWORDS FRBs, Instrumentation, ISM

IAUS 369
#2152

Probing the highest-energy FRB repeater bursts using thousands of hour observing campaigns

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The burst energy distributions of repeating fast radio burst (FRB) sources are an important diagnostic of the emission process. To date, burst energy distributions have only been studied for a few active repeaters, and are limited both by telescope sensitivity (for the weakest and most common bursts) and on-sky time (for the brightest and rarest bursts). Though there is evidence for a characteristic lowest energy scale in the case of FRB 20121102A, the upper-limit to the burst energies of repeaters is poorly constrained. FRB 20201124A is one of the most active repeaters known, and it produces bursts that are easily detectable even with a modest 25-m radio telescope. We observed FRB 20201124A for more than 3500 hours over the last year, using multiple European radio dishes in Onsala, Stockert, Torun and Westerbork. We detected more than 50 high-fluence bursts (>10 Jy ms). All these bursts were detected at 1.4 GHz and showed no counterpart in simultaneously recorded 350-MHz or 5-GHz observations (in the cases when multi-frequency coverage was available). Our sample of detected bursts consists of some the brightest FRBs ever observed, with fluences ~1 kJy ms. I will present this sample and show how it constrains the high-energy burst distribution of this source.

KEYWORDS fast radio bursts, FRB20201124A, high-energy burst distribution

IAUS 369
#1096

Cosmological uses of Fast Radio Bursts

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I will present how we can use FRB dispersion measurement DM(z) to probe the cosmology and intergalactic medium, complementary to the existing techniques. We first look at the missing baryon problem and analyze where most of the baryons are. I will utilize Illustris simulation and show where most of the DM contribution comes from. I then compare our estimates with the existed observations of diffuse baryons from the Sunyaev-Zeldovich effect. I will then discuss prospective constraints on cosmological parameters. By including realistic intrinsic scatters in the data caused by a number of factors, I will show that with 100 FRBs one can achieve quite good constraints on the diffuse gas fraction, and other cosmological parameters by combining with CMB and galaxy BAO data sets.

KEYWORDS FRB, missing baryons, simulation, large-scale structure, cosmological parameters, dispersion measure, Sunyaev-Zeldovich effect

IAUS 369

#2696

Constraining the value of Hubble's Constant using the Redshift-Dispersion Measure distribution of observed Fast Radio Bursts

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The statistical disagreement between different measurements of the value of the Hubble's constant, which determines the present day expansion rate of the Universe, has led to the long standing Hubble Tension. Assuming a flat ΛCDM model, there exists a 4σ to 6σ tension between early time probes of expansion using Cosmic Microwave Background (CMB) data from Planck compared to measurements based on the local distance ladder consisting of sources such as Type Ia supernovae (SNe Ia) and Cepheids. We work on constraining the value of Hubble's constant by using a sophisticated model of Fast Radio Burst (FRB) observations from ASKAP and Parkes radio telescopes, which act as independent cosmological probes. We fit the Redshift-Dispersion Measure (z-DM) relationship of FRB populations after accounting for the intrinsic luminosity function, cosmological gas distribution, population evolution, host galaxy contributions and observational biases due to burst width, dispersion measure and telescope beamshape. Using this model, we present a new constraint on H0 based on 16 ASKAP FRBs localised by the CRAFT/F4 collaboration and 60 unlocalised FRBs. We also perform a forecast using a mock sample of 100 localised FRBs, expected to be detected with the CRACO upgrade to ASKAP, to verify the accuracy of our model. This further demonstrates the potential for high-precision measurements of H0 (upto ± 2 (km/s)/Mpc) with extended datasets, which can alleviate the current Hubble Tension in the near future as the sample of observed FRBs grows exponentially.

KEYWORDS statistical methods, fast radio bursts, hubble's constant, maximum likelihood

IAUS 369

#2558

The FLIMFLAM Survey for FRB Foreground Mapping

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The 'Missing Baryon Problem' has been resolved thanks to recent samples of localized FRBs with measured redshifts, but major questions remain regarding the relative distribution of cosmic baryons in the diffuse IGM vs galactic halos, and the extent of the latter, with implications for galaxy formation and feedback models. Constraining the relative cosmic baryon distribution, however, is challenging due to the large cosmic variance in the line-of-sight baryon distribution at fixed FRB redshift due to the cosmic web as well as individual intervening galaxy haloes. I will show that this issue can be mitigated by measuring the spectroscopic redshift distribution of foreground galaxies in front of localized FRBs in order to map out the cosmic web as well as characterize intervening galactic halos. I will describe FLIMFLAM, an ongoing 40-night spectroscopic survey on the Anglo-Australian Telescope (and other facilities) that will map the foregrounds of ~20-30 localized FRBs primarily detected by CRAFT/ASKAP and localized by the F^4 collaboration. FLIMFLAM will provide the first direct constraints on the relative partition of baryons in the CGM and IGM, as well as on the characteristic sizes of galaxy CGM halos. I will also present recent results on FLIMFLAM observations of FRB190520 and FRB20210117, which are localized FRBs with unusually high DM given their redshifts. Our data will help confirm whether these high DMs arise from the foreground halos and large-scale structure, or whether they are caused by a high host DM.

KEYWORDS fast radio bursts, galaxy surveys, missing baryons, large-scale structure

IAUS 369
#2235

Searching for the source of excess extragalactic DM of FRBs

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Fast radio burst (FRB) dispersion measures (DMs) from radio observations record the presence of ionized baryons that are otherwise invisible to effectively all other techniques. Therefore, with FRBs, we may resolve the matter distribution in the cosmic web to offer unique constraints on our cosmological paradigm. The number of FRBs localized to their host galaxies has steadily increased to tens of FRB sightlines. Thus motivated, we have designed the FLIMFLAM survey, to obtain redshifts of the foreground galaxies proximal to FRB sightlines to independently estimate the FRB DM. For a few sightlines, we have already obtained spectra of hundreds of field galaxies using the AAT/AAOmega and the Keck/LRIS and DEIMOS spectrographs. The survey aims to study ~30 sightlines to produce <10% constraints on key parameters describing baryonic distribution in the universe. These include the fractions of baryons in the diffuse intergalactic medium and in the circumgalactic medium of galactic halos. Our sample continues to grow and preliminary analysis is underway. Meanwhile, a handful of these sightlines is interesting as they exhibit a significantly high excess in extragalactic DM (i.e. the DM from outside the Milky Way) in comparison to the mean value expected at their host redshifts from the Macquart Relation. In this talk, I will present the results of our latest work where we leverage the data collected for the FLIMFLAM survey to constrain the contribution of the foreground cosmic web to their DM excess.

KEYWORDS IGM, CGM, cosmology, FRB

IAUS 369
#2500

What can we expect from FRB gravitational lensing?

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Gravitational lensing of fast radio bursts (FRBs) offers an exciting avenue for several cosmological applications. However, it is not yet clear how many such events future surveys will detect nor how to optimally search for them. I have taken the known properties of FRBs and built a forecast for detection rates of gravitational lensing on delay timescales from microseconds to years, corresponding to lens masses spanning fifteen orders of magnitude. I will discuss these prospects for upcoming surveys DSA-2000, CHORD, and a coherent all-sky monitor that will have 25x the field of view of CHIME but with the same sensitivity (for example, BRST). In my talk I will also present a new application of FRB gravitational lensing that will measure directly the circumgalactic medium of intervening galaxies.

KEYWORDS FRB, gravitational lensing, cosmology, CGM

IAUS 369
#1094

The Effect of Gravitational Lensing on Fast Transient Event Rates

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Fast cosmological transients such as fast radio bursts (FRBs) and gamma-ray bursts (GRBs) represent a class of sources significantly more compact than any other cosmological object emitting electromagnetic waves. As such they may be sensitive to significant magnification via gravitational microlensing. Low mass primordial black holes are one such lens candidate which may constitute a significant fraction of the Universe's dark matter. Current observations only constrain their density in the nearby Universe giving FRBs the potential to form complementary constraints. Motivated by this we calculate the effect that gravitational lensing from a cosmological distribution of compact objects would have on the observed rates of FRBs and GRBs. With no confirmed progenitor, there is still some debate as to whether FRBs are intrinsically energetic or regular phenomena that are highly lensed. We rule out the prospect that all FRBs are gravitationally lensed by compact objects larger than 0.01 solar masses and explore the <10% level effects that a moderate amount of lensing could have on the observed rates for both FRBs and GRBs. FRBs will also be prone to wave optics effects and as such we also briefly treat these effects in the context of a rate calculation.

KEYWORDS Fast Radio Bursts, Gamma Ray Bursts, Gravitational Lensing, Rates, Wave Optics, Primordial Black Holes

IAUS 369

#1945

Finding the signature of a dwarf galaxy halo on a fast radio burst

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Fast radio bursts (FRBs) continue to prove themselves exceedingly useful as probes of extragalactic and circumgalactic matter, with the spectral, temporal and polarimetric properties of the burst encoding information about ionized material and magnetic fields along the line of sight. This includes any foreground galaxies and their haloes encountered by the FRB. Thus far, two events known to cross a foreground halo have been reported, FRB 20181112A and FRB 20191108A. We discuss a third event localized with ASKAP, found to intersect with the haloes of several spectroscopically-confirmed foreground galaxies. These objects include a galaxy with an impact parameter to the FRB sightline of just 12 kpc, the stellar mass of which (~108.2 $M_{\odot}$) places it in the dwarf regime, with the corresponding halo mass estimated at 1010.7 $M_{\odot}$. Low-mass (<1011 $M_{\odot}$) haloes are yet to be properly explored, and some models predict them to be evacuated of gas. This work constitutes the first direct exploration of a dwarf galaxy halo, and a novel opportunity to distinguish between feedback mechanisms in galaxies.

KEYWORDS fast radio burst, halo, dwarf galaxy, foreground galaxy, circumgalactic medium

IAUS 369
#2604

Constraining the dispersion measure and rotation measure contribution of FRB host galaxies using IllustrisTNG50

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As the number of observed Fast Radio Bursts (FRB) increases rapidly, their observed Dispersion Measures (DM) and Rotation Measures (RM) will be used as important cosmological probes to study the cosmic baryon density and the magnetic field of the intergalactic medium (IGM), respectively. However, the observed DM and RM of FRBs consist of multiple contributors that we need to take into account to recover the DM and RM of the IGM. Our work places constraints on the DM and RM contribution of FRB host galaxies up to redshift of 2, using galaxies from the state-of-the-art cosmological MHD simulation IllustrisTNG50. We find that due to the evolution of SFR with redshift in main sequence galaxies, the rest-frame DM increases, and the DM distribution is well represented by a lognormal function. In contrast, the rest-frame RM distribution of host galaxies is symmetric about 0 rad m-2, and is best modeled by a combination of Lorentzian and two Gaussian functions. The width of the RM distribution increases non-linearly with redshift up to z~1.5, beyond which it decreases capturing the effect of decreasing B-field strengths in galaxies at those redshifts. I will also discuss how the distributions of DM and RM change depending on stellar mass, galaxy inclination, location of the FRB in the hosts, and for main-sequence and quenched galaxies. We show how the host DM and RM of well-localized FRBs, e.g. FRB190806 can be constrained. In the case of FRBs without known redshift, our results suggest a common DM host estimate can be used, as the redshift dilution cancels out the increase of rest-frame DM with redshift. We will also discuss the best FRB redshift range for IGM studies. The trends in the variation of |RM| with redshift we have extracted for FRBs will be instrumental in pinning down the RM originating in the IGM and thereby robustly constrain the properties of magnetized plasma in the largest cosmic structures in the Universe.

KEYWORDS galaxies: magnetic fields, intergalactic medium, galaxies: evolution, galaxies: ISM

Inferring the FRB Distance and Energy Distributions with CHIME/FRB

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The first Canadian Hydrogen Intensity Mapping Experiment Fast Radio Burst (CHIME/FRB) catalog represents the first large and uniformly-detected sample of FRBs. By injecting synthetic pulses into our detection pipeline, we are able to account for observational biases and characterize the underlying FRB population. We present a study of FRB population parameters that also calibrates for selection effects using the CHIME/FRB Catalog 1 sample. We fit a model for the FRB energy distribution and the host galaxy DM contribution. Simultaneously, we infer the volumetric rate of FRBs and fit for the cosmic evolution of FRBs with star formation rate. We obtain tight constraints on the energy distribution, which we model as a Schechter function. Proposed models for FRB progenitors should be consistent with the energetics and abundances of the full FRB population predicted by our results. Finally, we infer the redshift distribution of FRBs detected with CHIME, which will be tested with the localizations and redshifts provided by the CHIME/FRB Outriggers project.

KEYWORDS FRBs, CHIME/FRB, CHIME, populations

IAUS 369

#1860

The Host Galaxies and Environments of Fast Radio Bursts

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Upgrades in multiple fast radio burst (FRB) experiments have led to a growing sample of precisely localized events, enabling host galaxy associations and detailed observations of the immediate environments surrounding FRBs. Such observations play a key role in elucidating the stellar populations that give rise to FRB progenitors. Indeed, host galaxy demographics, as well as the spatial offsets of FRBs from their host galaxy centers, can be used to inform progenitor channels. The localizations of two repeating FRBs to dwarf galaxies, their coincidence with persistent radio sources, and their large observed excess dispersion measures (DMs) stand in stark constrast to other localized events, which generally reside in more massive galaxies and exhibit modest excess DMs. These more massive hosts also indicate a preference for a population of AGN and low ionization nuclear emission line region (LINER) galaxies. Understanding this dichotomy among FRB hosts, as well as the origin of the hard radiation fields observed in a subset of sources, will provide critical insight into the stellar populations prevalent in FRB host galaxies and hence their likely progenitors. In this talk, I will review our current knowledge of FRB progenitors based on the properties of a small, but growing sample of host galaxies. I will also outline key follow-up observations that will lend to detailed characterizations of the galactic and local environments of FRBs, thereby shedding light on their progenitor channels.

KEYWORDS fast radio bursts, transients, magnetars, galaxies, extragalactic radio sources, neutron stars

IAUS 369

#1704

A search for persistent radio sources associated with repeating fast radio bursts from CHIME/FRB

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The finding of persistent radio sources (PRSs) coincident with two repeating fast radio bursts (FRBs; FRB121102 and FRB190520) supports non-cataclysmic models for FRBs and their progenitors. However, the non-detection of a PRS for the nearby repeating FRB 20180916B highlights the diversity of the properties and local environments of repeating FRBs. These results make clear the need for a statistical study of FRBs and PRSs to understand their nature. Due to the difficulty of localizing FRBs to sub-arcsecond precision and given that CHIME/FRB has now found more than 50 repeating FRBs with arcminute localizations, we have searched for PRSs within the error regions of CHIME/FRB repeaters. From VLASS data at 3 GHz, we find that most repeating FRBs do not have an associated PRS down to a 5σ detection threshold of ~600 μJy. We have also conducted a deeper search using the realfast/VLA program for selected FRB fields, with a 5σ level detection threshold of ~20 μJy at 1.5 GHz. We report some of the deepest upper limits available on the luminosity of the PRSs so far for some FRBs and describe the properties of the radio sources found within the fields. We discuss our results in the context of existing FRB-PRS models and compare them with the properties of FRB121102 and FRB190520.

KEYWORDS Fast Radio Bursts, Persistent Radio Sources, FRB121102, FRB190520

IAUS 369

#1170

VLBI Localization of a One-Off FRB to an Edge-On Galaxy

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Precise localizations of fast radio bursts (FRBs) within their host galaxies enables discrimination between progenitor models. Until now, localizations on continental-scale baselines have only been obtained through follow-up observations of repeating sources. Using the Canadian Hydrogen Intensity Mapping Experiment (CHIME) and two traditional telescopes at ~3000 km baselines, we demonstrate the localization of FRB 20210603A using very long baseline interferometry (VLBI) at its time of first detection. Our localization contour has a 95% width of 80 milliarcseconds on both of our baselines. We localize the burst to an edge-on disk galaxy at z = 0.177. The localization, dispersion measure, rotation measure, and temporal broadening of the FRB are consistent with an observed line-of-sight through the host galactic disk, suggesting a progenitor from a young population coincident with the host galactic plane. In the near future, sub-arcsecond localizations within the host galaxy will be possible for a large sample of non-repeating FRBs using CHIME/FRB Outriggers. This will enable robust cosmological studies with FRBs, and constrain their origin and host environments.

KEYWORDS CHIME, VLBI, localization, cosmology

IAUS 369
#1134

A commensal detection of HI and FRB localisation with ASKAP

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While analysis of localised FRB host galaxies typically focuses on the stellar component, neutral hydrogen (HI), traced through the 21-cm transition with radio telescopes, informs us on the gas content of galaxies. The HI distribution can reveal to us the history of the galaxy, such as merger events that may not be evident from the stellar information alone. This is an important consideration for understanding the environments of FRBs and their progenitors. We report on the commensal detection and localisation of FRB 20211127, and the detection of HI emission in the FRB host galaxy. This collaboration between the CRAFT and WALLABY survey teams on the ASKAP telescope marks only the fifth FRB host galaxy detected in HI. We report on the HI properties of the host galaxy, and compare to the early trend that has emerged in previous detections of asymmetric HI profiles or disturbed spatial maps in the host galaxies of FRBs.

KEYWORDS FRB, host galaxy, HI, neutral hydrogen, asymmetry, localisation, CRAFT

IAUS 369
#826

A growing diversity in the types of host galaxies and local environments for fast radio bursts

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Fast radio bursts (FRBs) are amongst the most energetic objects in our Universe, but despite several plausible models, their origin remains a mystery. In the absence of multi-wavelength counterparts to extragalactic FRBs, analyses of their host galaxy environments are presently the most informative path to identifying their progenitor systems. Thanks to interferometers, we can now localise FRBs with arc-second accuracies to the galaxies they originate from, and in some cases even pinpoint the burst to a region within the galaxy. In this talk, I will present the global properties of the FRB host galaxies focussing on a differential analysis of one-off and repeating FRB host population. I will also discuss the growing evidence for diversity in the types of host galaxies and local environments for FRBs, with a particular emphasis on the detection and localisation of a new non-repeating burst with the Australian Square Kilometre Pathfinder (ASKAP) and its similarities with other active repeating FRBs. Finally, I'll discuss the developments underway for future FRB searches and localisation with ASKAP.

KEYWORDS Fast radio bursts, Galaxy, ASKAP

IAUS 369

#1797

Implications from the first MeerTRAP Fast Radio Burst sample

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Fast Radio Bursts (FRBs) are incredibly luminous radio transients of micro to millisecond duration that originate from cosmological distances at inferred redshifts of up to a few. Despite rapid progress over the last 15 years since their discovery and several hundreds of recent FRB discoveries, their physical origins remain a mystery. Many proposed theories relate them to magnetar outbursts or cataclysmic events, such as compact object mergers or stellar explosions. The field has recently been strongly driven by results from wide-field radio interferometers operated by various international collaborations.

Since late 2019, our MeerTRAP team has carried out an FRB survey at the MeerKAT radio telescope in South Africa, a precursor to the Square Kilometre Array. In my talk, I will introduce the MeerTRAP FRB sample discovered so far, amounting to about two dozen new FRBs. In particular, I will quickly discuss their sample properties, such as their observed burst morphologies, scattering and scintillation parameters and what they tell us about intervening ionised media. I will then focus on what we infer from this first MeerTRAP sample regarding the FRB all-sky rate at 1.28 GHz and the scaling of FRB rate with burst fluence, especially at the low fluence end of the known FRB population only accessible to highly sensitive instruments such as MeerKAT. Finally, I will mention the implications of these results for cosmology and FRB progenitor models, for example, the FRB - magnetar connection.

KEYWORDS fast radio bursts, transients, cosmology, interstellar medium, radio interferometers, data analysis, surveys

IAUS 369

#1754

Observational constraints on FRB progenitors

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In the last few years, the Fast Radio Burst (FRB) field has made tremendous observational progress. The total number of published FRBs has exceeded 600 of which 20 have been localized to a host galaxy, with examples from both younger and older stellar populations. Several dozen FRBs have been seen to repeatedly burst, and chromatic periodic activity cycles have been identified in two sources. FRBs have been detected by at least 12 radio telescopes, where emission has been seen from as low as 110MHz to as high as 8GHz. While the nature of FRBs is still an open question, interesting constraints are emerging from these observational clues. In this talk, I will review the major observational results in the FRB field and summarize what we have learnt so far regarding the provenance of FRBs.

KEYWORDS FRB, radio, transient, observational

IAUS 369
#1967

Propagation effects in fast radio bursts as seen by the LOFAR telescope

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LOFAR has detected bursts from the periodically active, repeating FRB 20180916B, down to frequencies of 110 MHz. The discovery of fast radio bursts (FRBs) at such low frequencies has opened a new window to characterise and understand these enigmatic extragalactic transients. Propagation effects such as Faraday rotation and scattering, which are especially pronounced at low frequencies, can be measured with unparalleled precision using LOFAR. These effects provide key clues to characterise both the emission mechanism and the local environment of FRBs. I will present new results from the continued monitoring of FRB 20180916B that further support its frequency-dependent activity cycle, and track variations in scattering, drift rates and Faraday rotation measure with time and activity phase. We quantify the depolarizaton of individual bursts towards lower radio frequencies, using the large fractional bandwidth of LOFAR. We also investigate whether the observed Faraday rotation deviates from the standard scaling that is proportional to the square of the observing wavelength. We use these effects to constrain the properties of FRB 20180916B's local environment, which is less extreme compared to other repeaters, but still apparently more dynamic than that of a typical, isolated pulsar. Lastly, I will summarise follow-up efforts to observe several other CHIME/FRB repeating FRBs with LOFAR, including the detection of a second repeater.

KEYWORDS radio transients, propagation effects, polarization, scattering, faraday rotation, low frequency

IAUS 369

#1317

Finding FRB Sources without FRBs

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Two Fast Radio Bursts (FRBs) have been precisely localized and associated with luminous persistent radio sources (PRS). It is not known what makes FRBs or PRS or how they are related. By understanding their relationship, we could gain insight to the nature of the FRB source(s) and potentially use PRS to find FRB sources directly. We compile FRB and PRS properties in order to discuss their relationship and estimate the density of FRB-emitting sources in the local universe. The cosmic source density is between hundreds to tens of thousands per cubic Gpc, assuming a single population with pulsar-like beam width. This density implies that PRS may comprise as much as 1% of compact, luminous (>10^29 erg/s/Hz) radio sources detected in the local universe. The cosmic density and phenomenology of PRS are similar to that of the newly-discovered, off-nuclear ``wandering'' AGN. We are using all-sky radio and optical surveys to identify PRS-like sources and test the hypothesis that they are sources of FRBs.

KEYWORDS fast radio burst, persistent radio source, radio surveys, transient astrophysics

The high-time resolution CRAFT FRB sample

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The Australian Square Kilometre Array Pathfinder (ASKAP) has been enabled by the Commensal Real-time ASKAP Fast Transients (CRAFT) collaboration to record the raw voltages of 3-second windows containing FRB detections. These data allow for the reconstruction of the electric field in both linear polarisations at the bandwidth-limited time resolution of about 3 nanoseconds. For every FRB ASKAP detects in real time, CRAFT therefore has an extremely flexible data set including full polarimetry, coherent dedispersion, and freely-shaped dynamic spectra. I will present the ever-growing sample of ASKAP FRBs, their properties, and potential insights into the nature of FRBs gained from CRAFT's high-quality data products. I will also highlight a new method to quantitatively assess uncertainties in the structure-optimising DM.

KEYWORDS FRBs, CRAFT, ASKAP, high time resolution

IAUS 369
#1807

Compelling Morphologies of Fast Radio Bursts with CHIME/FRB Baseband Data

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Fast Radio Bursts (FRBs) are a class of highly luminous extragalactic radio transients that occur on micro-to-millisecond timescales. Investigations into the underlying progenitors and emission mechanisms of FRBs, the likes of which remain a mystery, have largely been limited by the availability of data at sufficiently high time and frequency resolutions with full-polarization information. The Canadian Hydrogen Intensity Mapping Experiment (CHIME) has detected thousands of FRBs, hundreds of which we now have the capability to study morphologically and polarimetrically at a high time resolution of 2.56 us using baseband data. From this rich sample of high-resolution data, we have selected sixteen one-off (non-repeating) FRBs and two bursts from repeating sources that exhibit morphologies of compelling complexity. These events were chosen based on their brightness and suggestive consistency (or lack thereof) with models of FRBs that have been put forward in the field thus far. Motivated by this diverse gallery of events, I show how we can draw new insights into emission mechanism and progenitor models of FRBs, paying particular attention to relativistic shock and magnetospheric scenarios. I also discuss the extent to which their morphologies and polarization properties can be explained by propagation through intervening media.

KEYWORDS Radio transient sources, High energy astrophysics

IAUS 369
#1717

Multi-year Polarimetric Monitoring of Repeating CHIME/FRB Sources (on behalf of the CHIME/FRB collaboration)

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Repeating Fast Radio Burst (FRB) sources exhibit temporal and/or frequency dependence in their polarized signals that is, in part, believed to be an imprint of inhomogeneities in the source's magneto-ionic environment. This property makes FRB polarization a powerful probe of the preferred environments of these mysterious sources. Motivated by these observations, I present new polarized measurements of nearly one hundred bursts from 13 previously published repeating sources detected by the Canadian Hydrogen Intensity Mapping Experiment (CHIME). I demonstrate how the ubiquity of burst-to-burst variations in the Faraday rotation measure of our sample suggest an association of repeaters with dynamic magneto-ionic environments and discuss the implications of this for different FRB progenitor models.

KEYWORDS FRBs, polarization, repeaters, progenitors, magneto-ionic medium

IAUS 369

#839

A Highly Variable Magnetized Environment in a Pulsar Binary resembling Fast Radio Bursts

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Recent polarimetry studies have shown that a noticeable fraction of the repeating FRBs display irregular, short-time variations of the Faraday rotation measure (RM). Moreover, evidence for rare polarized propagation effects such as Faraday conversion and polarized attenuation is seen in one FRB repeater. Together, they suggest a highly variable magneto-active circum-burst environment. We report similar polarization behavior in a pulsar binary system. We observe irregular short timescale changes of RM with both signs at random orbital phases as well as the profile changes of the circular polarization when the pulsar is behind the companion. The latter provides strong evidence for Faraday conversion and circularly polarized attenuation. The similarity of the polarization behaviors of the binary system and some FRB repeaters, the possible binary-produced long-term periodicity of two active repeaters, and the discovery of a nearby FRB in a globular cluster, where pulsar binaries are common, all possibly suggest that some fraction of FRBs have binary companions.

KEYWORDS FRB, pulsar, binary, polarimetry, Magneto-active, transient, RM

IAUS 369
#2395

Searching for FRB persistent radio source counterparts in dwarf galaxies using LOFAR

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FRB 20121102A, the first known repeating FRB, was localized to a star-forming region in a dwarf galaxy and found to be co-located with a persistent radio source (PRS). Its high and variable rotation measure demonstrates that it lives in an extreme magneto-ionic environment—unlike the bulk of the known FRB population. FRB 20190520B is only the second known source sharing phenomenology akin to FRB 20121102A's, with similar burst activity, host galaxy properties, as well as being associated with a PRS. PRS emission is potentially a calorimeter, allowing us to estimate the energy output of the central FRB engine. PRSs have also been discussed as a new class of extragalactic radio source, sharing observational similarities with intermediate mass black hole candidates. To improve our understanding of PRSs, it is imperative to increase the known sample size. Here, we present a targeted search for compact radio sources coincident with dwarf galaxies, using the LOFAR Two-Meter Sky Survey (LoTSS) second data release as our radio reference catalog. I will discuss source candidates selected as having radio luminosities greater than what is expected from star-formation activity in the host. Based on our candidate sample, I will examine the PRS space density and the rate of FRB events per persistent source. Finally, I will discuss planned VLBI follow-up observations to conclusively determine the compactness of these sources—a critical step towards establishing them as potential FRB hosts.

KEYWORDS FRB, PRS, LOFAR

IAUS 369

#2069

Monitoring repeating fast radio bursts with the Nançay Radio Telescope

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Using the Nançay Radio Telescope, we have established a monitoring campaign called ÉCLAT (French for "burst", stands for "Extragalactic Coherent Light from Astrophysical Transients"), which is targeting a number of known and active repeating fast radio burst (FRB) sources. ÉCLAT aims to provide the first large sample of bursts from repeating FRBs, with full polarimetry and high time resolution (~10 microseconds), at frequencies higher than the CHIME/FRB band. The observing frequency range extends from 1.1 to 3.5 GHz, ideal for comparative studies with lower-frequency burst samples from CHIME/FRB, uGMRT, LOFAR, etc.. This is also an interesting frequency range to explore the apparent depolarisation of repeating FRBs towards lower frequencies. The high time resolution of ÉCLAT allows us to search for microsecond structure in the bursts of FRBs, as well as to search for isolated bursts with durations of a few microseconds. Acting as a proof-of-concept, with ÉCLAT we can explore the feasibility and scientific productivity of such a short-timescale burst search. Furthermore, ÉCLAT's regular cadence and long term monitoring (~2 years) will assist in mapping activity cycles and the changing properties of these FRBs, such as dispersion and rotation measure. I will introduce ÉCLAT and share some of the first results from the first 6 months of monitoring.

KEYWORDS Monitoring, Repeaters, FRBs

IAUS 369
#1976

Deciphering the origin of FRBs with Apertif

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The Fast Radio Burst (FRB) field is currently thriving, thanks to the large number of instruments that have been carrying out dedicated FRB observations in the past few years. As a result, hundreds of new burst have been detected, tens of FRB host galaxies have been identified, and two dozen FRBs have been seen to repeat. This opens the possibility of conducting studies on large burst datasets, which will eventually lead to a confident identification of their progenitors.

Apertif, installed at the Westerbork Synthesis Radio Telescope in the Netherlands, has carried out an FRB survey at 1370 MHz between 2019 and 2022, during which we have followed up known repeating FRBs and detected two dozens of new one-off events.

In this talk, I will present the new Apertif FRB discoveries and explain the important implications we have been able to derive about the distribution of FRB parameters, the media through which they propagate, and the sources that originate them.

Regarding one-offs, the Apertif FRBs reveal a population of highly scattered bursts that are missing from the CHIME/FRB distribution due to their lower observing frequencies. This scattering is produced either in the circumburst environment or the FRB host galaxy. Furthermore, we observe a higher number of multi-component FRBs than CHIME/FRB, which can be explained by the lower scattering at higher frequencies and the higher Apertif time resolution. Multi-component bursts can offer important clues about FRB progenitors. We have put this to test with FRB20201020A, a burst showing five components with quasi-periodic spacing that are most likely explained by the magnetospheric structure of a magnetar.

This structure shares timing properties with some repeater bursts that we have detected with Apertif. I will further discuss what we learned from our detections of the repeating FRBs 20180916B, 121102, 20201124A and 20190208A, and from our non-detections of other repeaters. Most CHIME/FRB repeaters present a much higher activity rate at low frequencies, as opposed to FRB121102. With the Apertif data, we are thus able to characterise the FRB population at 1370 MHz and to better constrain the nature of FRBs.

KEYWORDS FRBs, magnetars, high-energy astrophysics, propagation effects, FRB progenitors

IAUS 369

#1446

A burst storm from FRB 20200120E in an M81 globular cluster

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The extremely nearby repeating fast radio burst source FRB 20200120E (in M81 at 3.6 Mpc) provides a bridge between Galactic sources of short-duration radio transients and the population of more distant extragalactic FRBs. Both the timescales and luminosities seen from FRB 20200120E probe an unexplored area of the short-duration transient phase space. The globular cluster origin of FRB 20200120E has raised interesting new questions about the nature of the source: is it a magnetar created through a more exotic formation channel than core-collapse, or could it be an extreme millisecond pulsar or compact binary system? Due to its proximity and novel location, FRB 20200120E is a highly interesting source to study in detail. I will present our monitoring campaign of FRB 20200120E with the 100-m Effelsberg telescope and its wide-band (400 MHz) voltage recording system. Since December 2021, we have detected 57 bursts from FRB 20200120E, 52 of which occurred within a single 40-minute window of time. To date, less than 10 bursts from FRB 20200120E have been presented in the literature. This newly detected burst storm allows us to explore the distribution of burst properties for FRB 20200120E, including burst durations, energies and wait times. We compare these with other well-studied repeating FRBs and Galactic neutron stars. We also apply strong constraints on any underlying periodicity in the burst arrival times. I will discuss these results in the context of FRB progenitor and emission models, and link to studies of the Crab pulsar, millisecond pulsars and Galactic magnetars.

KEYWORDS fast radio bursts, FRB, neutron stars, pulsars, Crab, magnetars, radio

IAUS 369
#1756

High Time resolution burst morphology of FRB 20180916B with CHIME/FRB

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FRB 20180916B is one of the most prolific repeating fast radio bursts (FRBs). Its unique 16 days periodicity and its relative proximity (150 Mpc) make it an ideal source to understand repeating FRBs. It was discovered by CHIME/FRB more than 3 years ago and since then the CHIME/FRB baseband system has recorded multiple bursts from the source. The baseband data available for more than 40 bursts enables us to study the FRB signal down to microseconds. This is the largest dataset available for this source at this time resolution. We provide precise estimates on scattering timescales and scintillation from the source, also mapping their evolution through time and activity phase to identify variations in the local environment. DM and burst width evolution have been examined to probe changes in the immediate environment of the source. The variations in these properties have been studied in complement with the polarization and RM evolution of the source presented by Mckinven et al 2022 to constrain the magneto-ionic environment. We also present drift rate measurements and sub-burst microstructure analysis providing stringent limits on the emission mechanism. We then investigate the burst-rate evolution of the source across the entire 3 year time period and its effect on these properties. In this presentation, I will show this large high-resolution burst sample from FRB 20180916B, present the strong constraints on the progenitor models that these bursts yielded and comment on the implications for the FRB repeater population.

KEYWORDS Fast Radio Bursts, Radio Astronomy

IAUS 369
#2164

Microsecond-duration bursts from FRB 20121102A

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The fast radio bursts (FRBs) observed to date typically last for order milliseconds. Bursts from FRB 20200120E, however, can be as short as ~50 microseconds, and some of these bursts show sub-structure down to ~60 nanoseconds. Probing FRB emission timescales constrains emission models. Motivated by the microsecond structure seen from some FRBs, we re-searched archival Green Bank Telescope data that targeted FRB 20121102A, the first-known repeater, at 4-8 GHz. Temporal broadening due to scattering is expected to be negligible at these high observing frequencies. Previous analyses of these data (see, e.g., Gajjar et al. 2018) detected close to one hundred bursts, with typical durations of ~700 microseconds. We used the voltage data available through the Breakthrough Listen project to coherently dedisperse and search these data at 2 microsecond time resolution. We also employed a systematic subband search across the 4.5 GHz of available bandwidth. These searches have led to the discovery of multiple new bursts, some of which are extremely short in duration, with their entire burst envelope lasting only ~5 microseconds. I will present a full polarimetric analysis of these bursts at 341 nanosecond time resolution, including an investigation of dispersion measure variations. This work demonstrates that there is a population of ultra-fast radio bursts that are undetectable by standard searches, and motivates us to further explore the transient phase space at microsecond time resolution.

KEYWORDS fast, radio, bursts, high-time-resolution, microsecond

IAUS 369

#284

FRB Emission mechanism theories vs. observations and population studies

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Since 2007 when the first FRB event has been anounced, many theoretical models explaining these enigmatic transients were proposed.

After discovery of an FRB-like radio flare from a Galactic soft gamma-ray repeator accompanied by a high-energy burst, the focus of theoretical studies is on magnetars. Still, there are many unsolved problems in the framework of the magnetar scenario. From the point of view of the emission mechanism, two main possibilities are discussed: a magnetospheric emission and radiation from a relativistic shock. In the talk I review both approaches and discuss their connections to the whole set of data on FRBs, including repetition, periodicity, spectral and polarization measurements, and population aspects.

KEYWORDS Fast radio bursts, magnetars, magnetospheres, relativistic shocks, maser emission

IAUS 369

#2333

Toward an Evolutionary Picture of FRBs

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Much efforts have been focused on explaining the energy source of fast radio bursts (FRBs), with magnetar being the front runner of the moment. The lack of obsevational constraints of the coherent length, even for pulsar emission, present a fundamental challenge.

With discoveries from the Commensal Radio Astronomy FAST Survey (CRAFTS), we have set a lower limit on the full-sky FRB event rate at 120K per day. It is naturally expected that the true event rate can be more than 1 million per day. It is possible and necessary to build a practical origin story while probing the physical principles. Also through CRAFTS, We have discovered one of the most robustly (no extended quiescent epoch) active repeater, FRB 20190520B, which has the largest host DM (both absolute and fractional value) known and only the 2nd FRB, after FRB 20121102A, with a compact persistent radio source counterpart. Both 190520 and 121102 can be located at the peripheral of a metal poor dwarf galaxy, favoring a star formation related origin over AGNs. Through a combined analysis of 21 FRBs including 9 repeaters, we have proposed a unified description based on multi-path scattering of the frequency evolution of FRB polarization. The magnetic field is also seen to reverse around active repeaters. With FAST, we have also published 1652 bursts from 121102 detected within 60 days, allowing for a robust rejection of any period between 1ms and 1h. An isolated magnetar thus looks unlikely for such an active repeater. In congregate, a plausible evolutionary picture of FRBs is within reach.

KEYWORDS FRB, repeater, RM, evolution

IAUS 369
#1489

Radio-loud magnetars as Galactic fast radio burst analogues

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Magnetars are a rare class of highly magnetised neutron stars. They are the primary source of local gamma-ray bursts and following the detection of FRB 200428 from the Galactic magnetar SGR 1935+2154, speculated to produce a significant fraction of cosmological fast radio bursts. Studying the local population of magnetars within the Milky-Way is therefore key to understanding these highly energetic objects and the role they play in the transient sky. Magnetars that emit radio pulses offer a unique insight into the magnetospheric conditions of these objects and may even represent Galactic analogues of FRB progenitors. In this talk I will present several key discoveries relating to these enigmatic objects using the latest generation of wideband instruments on the Parkes and MeerKAT telescopes, and via reprocessing of archival Parkes observations. These include the serendipitous discovery of transient Faraday conversion following a high-energy outburst, detections of giant radio pulses composed of quasi-periodic sub-pulses, and a sample of unusual narrowband pulses that bear a striking similarity to bursts seen from repeating FRB sources.

KEYWORDS Magnetar, Fast radio bursts, Neutron Star

IAUS 369

#1910

Radio nebulae from ULX Bubbles as Precursors of Common Envelope Events and Persistent Counterparts to Fast Radio Bursts

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The discovery of periodicity in the arrival times of FRBs, and some of them being localized to old globular clusters pose a challenge to the young-magnetar-based FRB models. The models that postulate that FRBs arise from magnetic reconnection or shocks in a relativistic outflow are not bound to magnetar engines; instead, they only require an impulsive injection of energy into a dense magnetized medium. Motivated thus, we had developed a scenario in which periodic FRBs are powered by accreting compact objects: the periodicity (on timescales of days to years) was attributed to Lens-Thirring precession of the polar accretion/jet funnel along which the FRB is beamed, which sweeps across the observer line of sight. As an extension, we develop a model whereby the expanding magnetized electron-ion nebula—as typically inflated by the accretion disk/jet winds (e.g., ULX "bubbles")—can naturally explain the observed properties of the persistent radio sources associated with some FRBs (e.g., size, flux, spectra, slope/decreasing trend in rotation and dispersion measures). We determine these properties by self-consistently evolving the distribution function of electrons heated by the disk/jet wind-ISM shock interaction, and are cooled by various radiative and adiabatic losses. Furthermore, our model also predicts luminous radio transients that may precede the common envelope events responsible for LIGO-BBH mergers, as may be discovered in VLASS or by future radio surveys. In my talk, I will present the model and the parameters expected from an accreting engine in order to satisfy the observed properties of the source.

KEYWORDS Fast Radio Bursts, Transients, Black Hole, Accretion, Jet, Stellar Evolution

Slowly rotating neutron stars as potential counterparts to repeating FRBs

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Fast radio bursts have the potential to unravel many cosmic mysteries through population studies of a well localised sample. Repeating FRBs in particular facilitate the understanding of both the local and intervening medium through time dependent pulse structure and polarisation studies. Previous studies and theoretical work have indicated that magnetars may be the progenitors for some of the repeating FRBs. Magnetars are slowly rotating neutron stars with periods longer than 2 s. Alongside the FRB-like bursts from the Galactic magnetar SGR 1935+2154, other radio-loud magnetars have shown flat polarisation angle and pulse microstructure, which are reminiscent of some repeaters. In this talk, I will present the sample of very slowly rotating (P > 10 s) Galactic transients discovered with the MeerTRAP instrument at the MeerKAT telescope. I will elaborate on the interferometric and beam localisation for the transients as well as cross-identification in the available archival multi-frequency data. I will explore the possibility of them being radio-loud magnetars or high-B pulsars and what the pulse structure can tell us about their possible links to repeating FRBs.

KEYWORDS Fast Radio Bursts, Magnetars

IAUS 369

#2496

Ultra-long Period Magnetars

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It is well known that there is a strong observational selection bias against long-period pulsating sources in radio surveys. Periodic windowing behavior, as (unexpectedly) discovered in some FRBs, is perhaps an important clue to the FRB radio mechanism or source requirements. Motivated by the 6.67 hour spin period isolated magnetar in supernova remnant RCW 103 (1E 161348–5055), Beniamini, Wadiasingh and Metzger (2020) proposed that the observed periods simply reflect the rotational periods of putative magnetars (who they dubbed ultra-long period magnetars). Giant flare kicks, charged particle winds, fallback accretion and other processes can all participate in angular momentum extraction resulting in a small fraction of magnetars attaining long periods. More recently the discovery of the Galactic ultra-long period magnetar candidates GLEAM-X J162759.5–523504.3 at ~1.3 kpc, as well as MeerTRAP's MTP0013 at ~300 pc strongly suggests a large population of long spin period and radio bright magnetars exist. In this talk I will discuss constraints and implications of these Galactic candidates on FRB periodicities and temporal evolution of magnetar fields.

KEYWORDS FRB, Magnetar, neutron star

IAUS 369

#3059

Multi-messenger and Multi-wavelength observations of FRBs

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Fulfilling the true promise of FRBs as cosmological probes, understanding their origins, and their association with other transients necessitates our understanding of the FRB emission mechanism, their formation channel(s), and their local environments. Most emission mechanisms expect that the prompt radio emission represents a small fraction of the total energy released — a larger fraction of the energy should be released at higher frequency wavebands: optical, UV, X-ray and in some cases, gravitational waves and neutrinos, either as prompt emission or as a longer-lived afterglow. Given that the observed rates of FRBs are two to three orders of magnitude higher than the sky rates of any other extragalactic transient, it is clear that most FRBs will not have detectable multi-wavelength counterparts. The X-ray bursts aligned with the FRB-like radio emission from SGR 1935+2154 highlight the need to be alert to the brightest and nearest FRBs since those will be the most likely to have detectable multi-wavelength counterparts. In this talk I will give an overview of the current and future efforts that are trying to search for multi-wavelength and multi-messenger counterparts to FRBs, specially focusing on optical and X-ray burst searches, FRB-GRB connections, and FRB-GW connections. I will talk about some of the recent results and constraints that have been obtained as well as the challenges going forward.

KEYWORDS

IAUS 369

#2467

Dissecting the radio/X-ray connection in the FRB-emitting magnetar SGR 1935+2154 and implications for the rest of the population

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The magnetar SGR 1935+2154 is currently the most active source of the population. Since its discovery in 2014, it has shown several major outbursts, including the April 2020 burst storm when several hundred X-ray bursts were observed in the span of hours. In its immediate aftermath, SGR 1935+2154 showed the first Galactic Fast Radio Burst (FRB), cementing the model of magnetars as progenitors of at least some extragalactic FRBs. Subsequently, the source has also shown a handful of weaker FRB-like radio bursts and a radio pulsar-like episode lasting about a month. We observed SGR 1935+2154 extensively during these subsequent events leading to the discovery of a temporally coincident large timing anomaly in the form of a rapid spin-down event or an "anti-glitch". I will discuss the implications of our discovery on the FRB-like bursts and radio pulsed-emission from SGR 1935+2154 and the ramification on the rest of the magnetar population. Finally, I will provide a comprehensive summary of our continued radio/X-ray monitoring of SGR 1935+2154 which covered two more large outbursts from the source in 2021. This wealth of data will provide a stepping stone towards a better understanding of the magnetar bursting and outburst activity as well as their FRB-like bursts and radio pulsed emission.

KEYWORDS Neutron stars, Magnetars, SGR 1935+2154, FRB, Pulsar, X-ray, Glitches

IAUS 369
#2398

Testing a neutron star merger origin for some FRBs

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Coherent radio emission in connection with neutron star mergers is predicted to occur on a variety of timescales ranging from seconds pre-merger to years post-merger. Indeed, neutron star mergers are thought to be possible progenitors for at least a subset of FRBs. In this talk, I will discuss two approaches of testing this hypothesis: 1) using localized FRBs and multiwavelength datasets to compare to relevant models, and 2) rapid-response radio observations triggered by short gamma-ray bursts (SGRBs) or gravitational wave merger (GWM) detections. In the former, I will use a subset of localized FRBs to demonstrate how key properties of merger-related models can be constrained with the help of any gamma-ray, X-ray or continuum radio data that are available. For the latter, I will show how we are triggering LOFAR on both Swift SGRBs and GWM events, allowing us to be on-source within a few minutes of the merger and probing key model timescales. I will present results using this strategy. Finally, I will discuss exciting prospects and improvements to our strategy in the era of LOFAR2.0 and for the upcoming GW observing run, which include greatly reduced triggering latencies and simultaneous beam-formed and interferometric observations of mergers.

KEYWORDS FRB, SGRB, neutron star merger, gravitational waves, multiwavelength

IAUS 369

#280

A MeerKAT, e-MERLIN, H.E.S.S. and Swift search for persistent and transient emission associated with three localised FRBs

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We report on a search for persistent radio emission from the one-off Fast Radio Burst (FRB) 20190714A, as well as from two repeating FRBs, 20190711A and 20171019A, using the MeerKAT radio telescope. For FRB 20171019A we also conducted simultaneous observations with the High Energy Stereoscopic System (H.E.S.S.) in very high energy gamma rays and searched for signals in the ultraviolet, optical, and X-ray bands. For this FRB, we obtain a UV flux upper limit of 1.39×10−16 erg cm−2 s−1Å−1, X-ray limit of ~ 6.6×10−14 erg cm−2 s−1 and a limit on the very-high-energy gamma-ray flux Φ(E > 120 GeV) < 1.7 × 10−12 erg cm−2 s−1. We obtain a radio upper limit of ~15 microJy beam−1 for persistent emission at the locations of both

FRBs 20190711A and 20171019A, but detect diffuse radio emission with a peak brightness of ~53 microJy beam−1 associated with FRB 20190714A at z = 0.2365. This represents the first detection of the radio continuum emission potentially associated with the host (galaxy) of FRB 20190714A, and is only the third known FRB to have such an association. Given the possible association of a faint persistent source, FRB 20190714A may potentially be a repeating FRB whose age lies between that of FRB 20121102A and FRB 20180916A. A parallel search for repeat bursts from these FRBs revealed no new detections down to a fluence of 0.08 Jy ms for a 1 ms duration burst.

KEYWORDS FRB, Radio continuum, galaxies, non-thermal

IAUS 369

#2431

FRB 20180916B observing campaigns using uGMRT and Effelsberg

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The repeating FRB 20180916B has a periodic active cycle of 16.33 days where bursts at 600 MHz arrive in a 1.6 day active window.It is known that the activity window depends on the frequency and that it arrives at an earlier phase at higher frequencies. The cause of the periodicity is still unknown but provides strong constraints on models. In this talk, we present a wide-band study of burst properties and the active window using 83 bursts detected with the upgraded Giant Metrewave Radio Telescope (uGMRT) at 650 MHz and 1.1 GHz and 8 bursts from the Effelsberg 100-m radio telescope at 4-8 GHz. Bursts from uGMRT span multiple cycles and phases, thus allowing us to study changes in burst rates, Polarization Position Angles (PPAs), Rotation Measures (RMs), and Dispersion Measures (DMs). We also detect two bursts simultaneously at 650 MHz and 1.1 GHz. We modeled the frequency dependence of the active phase as a power law and targeted observations in the predicted active windows of 6 GHz with Effelsberg. These observations led to eight burst detections, the highest frequency detections of FRB 20180916B to date. These bursts are narrower in time and possess larger spectral widths compared to lower frequencies, and one burst exhibits sad-trombone structure. They have flat PPAs and high polarization fractions. They also exhibit diffractive scintillation due to the Milky Way and follow f^4 scintillation bandwidth scaling. We discuss the implications of chromaticity on the source models. Lastly, we also study PPAs from 6 GHz, 1.1 GHz, 650 MHz against phase, and test various magnetar models.

KEYWORDS FRB, transients

IAUS 369

#2589

High time-resolution optical limits on bursts from repeating FRB 20190520B by simultaneous 24.4 fps observations with Tomo-e Gozen

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We conduct 24.4 fps optical observations of repeating FRB 20190520B using Tomo-e Gozen, a high-speed CMOS camera mounted on the Kiso 105-cm Schmidt telescope, simultaneously with radio observations carried out using the Five-hundred-meter Aperture Spherical radio Telescope (FAST). We succeeded in the simultaneous optical observations of 11 radio bursts that FAST detected. However, no corresponding optical emission was found. The simultaneous optical fluence limits for individual bursts are as deep as 0.068 Jy ms, and 0.029 Jy ms when the data for the 11 radio bursts are stacked, corrected for the dust extinction in the Milky Way. The extinction corrected fluence limit is deeper than those obtained in the previous simultaneous observations for an optical emission with a duration a few ms. Although the current limits on radio optical spectral energy distribution (SED) of FRBs are not constraining, we show that a simultaneous optical emission from an FRB can be detected by a similar optical observation as ours for a brighter FRB with a radio fluence larger than 5 Jy ms, based on some empirical and theoretical predictions.

KEYWORDS Radio transient sources, Optical observation, Time domain astronomy

Searching for FRB-like Counterparts from GRBs using the First CHIME/FRB Catalog

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Fast Radio Bursts (FRBs) are a class of highly energetic transient events, lasting for a few milliseconds and originating from extragalactic distances. While over 750 FRBs have so far been published, very little is known about their origins. Some theories for extragalactic FRBs predict accompanying high energy emission, but none has so far been detected. In this work, we use the Canadian Hydrogen Intensity Mapping Experiment (CHIME) Fast Radio Burst (CHIME/FRB) Project to explore whether any FRB-like emission is associated with 69 gamma-ray bursts (GRBs) detected between 29th August 2018 and 2nd July 2019. We do this by searching for any GRBs that are temporally and spatially coincident with FRBs from the first CHIME/FRB catalog. We also search for GRB-FRB pairs within the time frame of the first CHIME/FRB catalog that are solely spatially coincident and find two such pairs, although the chance probability of this occurring is high for our given sample. Lastly, we use CHIME/FRB to constrain FRB-like radio emission before, during, and after the high energy emission for 33 GRBs. Our most constraining radio limits for short gamma-ray bursts (SGRBs) are <20 Jy at 19 ks pre-high-energy emission, and <5 Jy at 28 and 38 ks post-high-energy emission. We use these limits to constrain certain models for radio emission from SGRBs. We also place limits as small as 1 Jy for long gamma-ray bursts (LGRBs), although radio emission associated with LGRBs has not been as strongly predicted.

KEYWORDS fast radio burst, gamma-ray burst, radio transients

IAUS 369

#2419

Candidate Faint Fast Radio Bursts Found by Citizen Scientists

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The Canadian Hydrogen Intensity Mapping Experiment Fast Radio Burst (CHIME/FRB) project only records fast radio burst (FRB) candidates above a signal-to-noise ratio (SNR) threshold of 8.5, due in part to lack of expert time to review candidates and lack of storage to record them until such review. Even a small reduction in this threshold would be expected to lead to a significant increase in detections of faint bursts, because of the corresponding increase in survey volume. Newly-detected bursts could be more distant, and hence useful probes of the intergalactic medium, or intrinsically fainter, with potentially different source mechanisms and morphologies.

We launched the citizen science project “Bursts from Space” to review all SNR 7.8 - 8.5 candidates detected by CHIME/FRB. Over the 1.5 years of the project so far, 4000 volunteers classified 42,000 candidate events as either “human” or “from space”. Promising (majority “space”, N=1958) candidates are more frequent at elevations where CHIME/FRB is more sensitive. Of our 140 most promising candidates, 59 were independently ranked by expert CHIME/FRB astronomers as “Confirmed” following the same assessment protocol as for standard CHIME/FRB classification of brighter bursts. It is possible for noise fluctuations to randomly align in a shape indistinguishable from a real burst, and hence any individual candidate cannot be definitively verified by visual inspection. We will describe our efforts to-date towards statistical verification.

Our faint sample shows several interesting properties as compared to the higher signal-to-noise CHIME/FRB sample. Future verification and expansion of the yield from citizen-identified events may allow us to identify new examples of unique or unusual bursts, improve our knowledge of repetition statistics and periodicities for repeating FRBs, and increase our sample of FRBs at the highest and lowest DMs. Volunteer classifications can ultimately be used to train deep learning algorithms, with the potential goal of detecting and triggering baseband recordings of faint bursts and thereby enabling high-resolution measurement of this FRB subset.

KEYWORDS fast radio bursts, chime, citizen science, machine learning, statistics

IAUS 369

#1785

A search for low-frequency FRB emission with the LOTAAS survey

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FRBs can be rendered undetectable at low frequencies due to scattering in the intervening medium or a spectral turnover, either intrinsic to the emission mechanism or due to propagation effects in the circum-burst environment. Low-frequency observations can thus help constrain the emission mechanism for FRBs and the properties of their local environments. Although emission from two repeating FRB sources has been detected in the low-frequency range below 300 MHz, it is as yet unclear what fraction of FRB sources emit in this frequency range. In order to develop a better picture of low-frequency FRB emission, we search archival observations made with the Low Frequency Array (LOFAR) telescope at the location of 482 FRB sources from the first CHIME/FRB catalog. The observations are each an hour in duration and were conducted as part of the LOFAR Tied-Array All-sky Survey (LOTAAS) in the frequency range of 119-151 MHz. I will report on the results of this search and discuss the resulting constraints on the frequency dependence of FRB activity.

KEYWORDS

IAUS 369

#691

Scattering Horizons for Fast Radio Bursts

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Radio wave scattering horizons constitute the regime where scattering renders fast radio bursts (FRBs) undetectable in time domain surveys. In this talk I will assess Galactic and extragalactic scattering horizons for the all-sky FRB population at a range of redshifts, using a combination of NE2001 to model dispersion and scattering from the Milky Way and independent electron density models for other galaxies with a range of masses, morphologies, and strengths of turbulence. FRBs at redshifts $z < 1$ have scattering largely dominated by host galaxies, whereas a hypothetical high-redshift ($z = 5$) FRB population has scattering dominated by intervening galaxies. About 20% of high-redshift FRBs are predicted to have scattering delays greater than 5 ms at 1 GHz, and over 40% of FRBs at redshifts $z > 0.5$ are predicted to have scattering delays greater than 1 ms at frequencies under 800 MHz. These percentages may be underestimated if scattering from the circumgalactic medium at higher redshifts is larger than the scattering of FRBs observed through nearby halos, such as FRB 2020012E, which indicates negligible scattering occurs in the halos of M81 and the Milky Way. Scattering horizons can therefore have a significant impact on the detection of high-redshift FRBs and the relevant cosmological applications that have been proposed. Our results suggest that large future samples of localized FRBs could resolve the redshift evolution of turbulence in both interstellar and circumgalactic media over the course of cosmic star formation history.

KEYWORDS Fast radio bursts, Interstellar medium, Circumgalactic medium, Scattering

e-Posters

IAUS 369

#3031

Multi-wavelength characterization of FRBs

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Fast radio bursts (FRBs) are short duration and luminous radio pulses detected at extragalactic distances. The current census of FRBs reported to date include more than 700 events with a relatively large event rate of ~10^3 per sky per day. While most FRBs are one-off events, there are now more than 20 repeating sources, suggesting a noncatastrophic origin for at least a subset of these events. Several hypotheses have been proposed for FRB progenitors and emission mechanism, which to date remain elusive. The repeating FRBs provide an opportunity to characterize the nature of the bursts and their emission mechanism. In particular multi-wavelength observations may be key as several classes of FRB models predict prompt multiwavelength counterparts. In this presentation, I will provide an overview of recent radio-X-ray-optical observation of a sample of repeating FRBs. In particular, I will discuss an on-going campaign to observe repeating FRBs with the NICER X-ray instrument with simultaneous radio observations with the Deep Space Network antennas. The joint observations are expected to provide key insight into the emission mechanism of FRBs.

KEYWORDS FRB, neutron star

IAUS 369
#465

Towards the Prompt Detection of Fast Optical Bursts

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The highly energetic emission mechanisms from which Fast Radio Bursts (FRBs) originate have been the subject of intense investigation in recent years. Yet to be verified, many current theories predict association of multi-wavelength bursts with FRBs. Some efforts have been made in the search of such bursts, but none have resulted in positive detections. A prime consideration has been the fact that the prompt emission from FRBs is extremely short in duration, which effectively precludes multiwavelength followup via traditional target-of-opportunity campaigns. The optical counterparts of prompt emission from FRBs, Fast Optical Bursts (FOBs), would elucidate understanding on the progenitor and environment of such events. Here, we investigate a novel approach to the serendipitous detection of FOB's through the fact that their seeing distorted images should look characteristically different than those of steady sources in a standard optical exposure of finite duration. In particular, for a steady source, the point spread function due to seeing involves an average over the distortions due to atmospheric turbulent structures that transit over the aperture while the image is being collected. In contrast, a fast optical flash of very short duration will exhibit distortions due to a much more limited patch of sky given by the projection of the primary aperture on the turbulent layers. As such, it will exhibit structure at higher spatial frequencies. We apply this idea to simulated observations with the Vera C. Rubin Observatory. We simulate FOB observations by tracing photons through an atmospheric model and a simulation model of the Rubin telescope. We compare these simulations to point-source star simulations of 15s duration, which is the nominal Rubin exposure time. A statistical power spectrum analysis is presented, showing relevant structural differences in the images that indicate the feasibility of distinguishing FOBs from point-source stars. We report the classification accuracy results of a Neural Network classifier on different FOBs. From this classifier, we derive constraints in duration-intensity parameter space for identifying FOBs in Rubin observations.

KEYWORDS Fast Radio Bursts, Multi-messenger Astronomy

IAUS 369
#2786

Multi-wavelength follow-up on the repeating FRB180916

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I will report on multi-wavelength follow-up of the repeating FRB180916. We have observed this FRB using GMRT, Onsala, Torun, and LOFAR at radio wavelengths, Gemini-N/'Alopeke high-cadence camera in the optical, XMM-Newton and NuSTAR in X-rays, and INTEGRAL and MAGIC in gamma-rays, from which we searched for transient emission that may be associated with the FRB events observed by CHIME. Although we had simultaneous optical and radio observations during a couple of CHIME bursts, we did not detect any multi-wavelength transients to deep limits at optical through gamma-ray wavelengths. I will discuss the implications of these limits and the novel constraints that can be placed using simultaneous, multi-wavelength observations.

KEYWORDS

IAUS 369
#2618

Constraining faint afterglow emission from Fast Radio Bursts

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The emission mechanism of Fast Radio Bursts (FRBs) is yet unknown though many different models have been proposed. Many FRB emission mechanisms predict that the relativistic plasma, after FRB emission, may continue to emit fainter radiation, not unlike afterglows observed from gamma-ray bursts and magnetar giant flares. This motivates us to constrain any faint afterglows or longer timescale emissions from FRB sources. Previously, Bhandari et al. (2020) have put limits on the long time-scale emission before and after a burst from observations of FRB 191001. In this project, we have put constraints on any faint afterglow or precursor emission over a timescale between 200 ms to 10 seconds by stacking 365 FRBs from CHIME/FRB Catalog 1. We also separately stacked 86 bursts from the repeating FRB 20180916B and 36 bursts from FRB 20201124A. We aligned dynamic spectra of all FRBs by peak and normalized by peak flux. We generated a control sample with the same noise signature to compare our final results by shuffling our data in time and treating it identically to the dynamic spectra of FRBs. After stacking, we fitted Gaussian and exponential decay models to the data with timescales from 200ms to 10s. Our new stacked limits are 2 orders of magnitude lower than the previous limits. At a 5-sigma confidence, we constrain the emission to be ~ 4×10-3 to 2×10-2 times fainter relative to the peak FRB flux.

KEYWORDS FRB afterglow, FRB precursor

IAUS 369
#2324

An Astronomical Observatory in Djebel Orbata (Gafsa): A proposal for an academic project in Tunisia

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Tunisia is one of the countries where Astronomy and Astrophysics courses are absent in the Tunisian universities, including higher, secondary, and primary schools. Astronomy in Tunisia is only taught as a small chapter in physics and geology courses, besides its significant impact on our world from technology development to economic growth, and society advancing by constantly pushing for instruments, processes, and software that are beyond our current capabilities including advances in imaging and communications.

Nowadays, thanks to the hard work of the astronomical association and club in Tunisia and the important role that outreach activities play in sensitizing people about the importance of astronomy in sciences and the education quality, many people have been interested to continue their studies and research in astronomy, physics and space science. Although we have focused mainly on technology and knowledge transfer, perhaps the most important contribution is still the fact that astronomy makes us aware of how we fit into the vast Universe. Astronomy is at the forefront of science and technology. It is a discipline that opens our eyes, gives context to our place in the Universe, and can reshape how we see the world.

Through this proposal of an Astronomical Observatory in Djebel Orbata (Gafsa), we are suggesting collaborative work between the Tunisian Ministries/Universities and international astronomical communities and any institute that have experience in such a project to realize an astronomical observatory that links astronomical committees in Tunisia and outboard and help to build the first academic Observatory, dedicated for sciences and astronomy education. The main objective of the Astronomical Observatory in Djebel Orbata is to implement astronomy courses in Universities and schools, giving the opportunities for students to continue their research projects and study astronomy and astrophysics. Another objective of this project is to consolidate the relationship between the national and international astronomical groups and open a new channel for future collaborative projects, especially since Tunisia conserves a good dark sky with low light pollution, which will allow many astronomers to enjoy the sky quality.

KEYWORDS Astrophysics, space science, Observatory, instruments, research, dark sky, collaborative projects

IAUS 369
#2182

Identifying which localised ASKAP FRBs repeat

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There has been various evidence in support of different pulse morphology between 'one-off' FRBs and repeating bursts such as sub pulse drifting, pulse duration and fractional bandwidth. We present a detailed analysis of the pulse morphology on the latest localised ASKAP FRB sample using the high-time-resolution data. With a localised sample of FRBs, we can better understand the line-of-sight propagation factors and intrinsic brightness of these bursts. By combining the distances, burst energies, morphology, host environments and follow-up observations of these FRBs, we compare the properties of FRBs with no repetition detected and the known repeating population to identify further differences between the two populations. We further discuss these implications with subsequent FAST follow-up observations for FRB210407, a localised FRB with the highest DM ever measured by ASKAP, 1784 pc cm-3.

KEYWORDS Fast Radio Bursts, Burst Morphology, Repeating FRBs, FRB 210407

IAUS 369
#1968

Real-time beamforming of pulsars for calibrating the CHIME/FRB Outriggers

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The Canadian Hydrogen Intensity Mapping Experiment/Fast Radio Burst (CHIME/FRB) project has observed a large sample of Fast Radio Bursts (FRBs) to date, making it one of the forerunners in the global quest to understand the nature and origin of FRBs. The CHIME/FRB Outriggers are a VLBI network of 3 CHIME-like antennas which will enable the localisation of FRBs to less than 50 milliarcsecond precision. The VLBI calibration of Outriggers poses a unique challenge as FRBs are fast transients occurring at unpredictable times and positions in the sky. Moreover, the stationary design of the Outriggers makes it impossible to steer towards known VLBI calibrators. To overcome this challenge, we plan to employ a novel approach of using pulsars spread over the entire sky as calibrators which will maximise the time a calibrator is in-beam. The implementation of this approach requires the real-time beamforming of pulsars every second, buffering the gated beamformed data and dumping the data upon an FRB event to enable offline phase-referencing. In this poster, we describe the real-time beamforming pipeline which will accomplish this non-trivial task with reasonable requirements of digital hardware.

KEYWORDS CHIME/FRB Outriggers, VLBI, Real-time Beamforming

IAUS 369

#1728

Radio/optical flux ratio analysis for extragalactic radio sources

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We analyze radio/optical flux ratios and try to find a connection between radio and optical fluxes for radio sources associated with different optical types. For that, we used FIRST and SDSS catalogues. By cross-correlation of these catalogues with a search radius of 15 arcsec it became possible to select 69,868 radio sources, which have one confident association and a second association farther than 15 arcsec. Having radio and optical fluxes, we estimated F(FIRST)/F(SDSS_r) and built a distribution of this ratio. Having the distribution, we could divide the ratios into 3 ranges: low radio range – F(FIRST)/F(SDSS_r) < 750, medium radio range – 750 ≤ F(FIRST)/F(SDSS_r) ≤ 1250 and high radio range – F(FIRST)/F(SDSS_r) > 1250. As a result, we have 48,955 radio sources in the low radio range, 6037 radio sources in the medium radio range, and 14,868 radio sources in the high radio range. The SDSS provides 2 redshifts for each of the 9980 sources: spectroscopic and photometric ones. We have shown that 68.9% of these sources have the same spectroscopic and photometric redshifts within sigma=12.5% after elimination of the systematic shift zspectro-zphoto=0.0073. We conclude that the photometric redshift is enough reliable when the spectroscopy is absent.

KEYWORDS radio sources, radio flux, optical flux, radio/optical flux ratios, absolute magnitudes

IAUS 369
#1656

Search for FRBs from southern magnetars

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We present the current status of a campaign searching for Fast Radio Bursts from southern magnetars. We use two 30-m radio telescopes at the Argentine Institute of Radio Astronomy. Both telescopes are identical and operate with a highest frequency of 1456 MHz and a total bandwidth of 50 MHz. In the first stage of the campaign, we observed the magnetars J1622-4950 and J1550-5418 for 10 days, with a maximum of 3 h 40 m each day. The analysis of the observations was performed with PRESTO software. Here we report our preliminary results and the prospects for the next stages of the campaign.

KEYWORDS FRB, magnetar, observations, radio telescope, southern hemisphere

IAUS 369
#1562

Calibrating the CHIME/FRB Outriggers using Pulsars and the VLBA

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The CHIME/FRB Outriggers project aims to use the Canadian Hydrogen Intensity Mapping Experiment (CHIME) Fast Radio Burst Project, plus three smaller outrigger telescopes, as a dedicated VLBI network to localize over 1,000 FRBs to ~50 mas precision within the first two years of operation. With this level of localization, the CHIME/FRB Outriggers will not only be able to identify an FRB's host galaxy but also resolve where within the host it is located. However, calibrating the Outriggers proves difficult and requires a novel approach. Thus, the Outriggers will use pulsars localized to ~mas as phase calibrators as pulsars are bright, radio point sources with a broad distribution of hour angles. In this poster, we outline this pulsar calibration strategy and then discuss our initial ~mas level pulsar localizations obtained using the Very Long Baseline Array (VLBA).

KEYWORDS fast radio burst, pulsars, radio instrumentation, calibration

IAUS 369
#1160

Searching for second-timescale radio transients with CHIME telescope

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The Canadian Hydrogen Intensity Mapping Experiment (CHIME) is a transit radio telescope operating across 400 - 800 MHz with a field of view of ~ 200 sq. degrees. The telescope has been regularly detecting Fast Radio Bursts using the CHIME/FRB system. The sensitivity of CHIME/FRB reduces with larger pulse widths due to the current design of the radio frequency interference (RFI) removal algorithms, making it challenging to detect bursts with widths > 50 ms. Hence, slower duration transients are as-yet unexplored and open parameter space. Possible sources for such radio transients could include flaring stars, compact binaries, radio counterparts of GRBs or counterparts of binary neutron star mergers. Here we present our transient search pipeline developed to detect slower duration radio transients (50 ms - 5 seconds) in the CHIME data. The search makes use of a well-established single pulse search routine from the pulsar search code PRESTO and then uses clustering techniques to distinguish potential astrophysical sources from noise. The novel setup is designed from inception to have a built-in system to inject simulated pulses (sampled across the DM, fluence and pulse width parameter space) in the real data and recover them using the pipeline. The statistics from the injection system are used to optimise the detection efficiency of the RFI removal algorithm, measure the false alarm rate, and measure the detection completeness of the pipeline. The pipeline will be deployed to detect slow radio transients in the data gathered for the CHIME Slow Pulsar Search project.

KEYWORDS Radio transient sources, Period search, Astronomy data analysis, Transient detection, Sky surveys

IAUS 369

#666

On measuring Ionised bubbles at high redshift

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I will explain a new method to measure the sizes of smoothly evolving ionised bubbles at the epoch of reionisation, using the ionising continuum photons (assuming they are emitted by galaxies) and the mean cosmic density, which is a function of the redshift.

I will show the advantages of our method, which are, our method can be used for individual sources and for proto-cúmulos. I will compare our method with other methods often used in the literature. Specially the method used by Yajima (2018) that it is commonly used. I will also explain why this later method gives very close results. Finally I will compare our method with other methods that have recently appeared in the literature. In particular, I will show that the method derived by Endsley and Stark (2022) gives very different results than other methods. In particular, this method has several parameters that are left to the user, thus not constrained by usual parameters.

KEYWORDS

IAUS 369
#421

An Arecibo Survey of M87 for Fast Radio Transients

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The giant elliptical galaxy M87, prompted by contentious historical burst detections, has been a subject of intense scrutiny in past searches for extragalactic fast radio transients. Incentivized by modern advancements in telescope sensitivity, we targeted the core of M87 for 10 hours with the 300 m Arecibo radio telescope in 2019. Here, we present results from our matched filtering searches for bursts with durations between 0.3–123 ms, and dispersion measures up to 5500 pc cm-3. Our analyses revealed an absence of astrophysical bursts in our 1.15–1.75 GHz data above a 7σ detection threshold. Our investigations thus constrain the burst rate from M87 to < 0.1 bursts/hr above 1.4 Jy ms, the deepest upper limits derived to date. Using insights gleaned from studies of giant pulses emitted by the Crab pulsar, we discuss the physical significance of our results for the potential neutron star population in M87.

KEYWORDS Radio transients, Fast radio bursts, Neutron stars

IAUS 369

#289

Constraints on the cosmological variation of the proton-to-electron mass ratio using a single H_2 system

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Studying spacetime changes natural constants is a better approach to exploring additional physics beyond General Relativity and the standard model, which is prompted by unification scenarios and dark matter and dark energy predictions. Using an H2 -single observational spectrum of QSO 0347-383, we offer a new approach to search for a cosmological variation in the proton-to-electron mass ratio. A direct estimate of the variation in the proton-to-electron mass ratio is obtained by comparing the separate ratio of the H2 line between observations and the laboratory. We derive a cosmological variation of the proton-to-electron mass ratio Δμ/μ=(-0.00027±0.00871) ppm at zabs=3.025 . This study demonstrates new approaches to investigating fundamental physics by tracking the QSO systems at high-redshift.

KEYWORDS varying physical constants, individual QSO 0347-383, QSO spectra analysis

e-Talks

IAUS 369

#2942

VERITAS's Gamma-ray and Rapid Optical Observations of FRBs

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Multi-wavelength follow-up of FRBs has proven a difficult challenge and the ability to probe different bands rapidly and simultaneously is key. The VERITAS array has the capability of constraining both rapid optical (0.4 ms sampling in the B band) and gamma-ray emission (200 GeV -> 10 TeV) from FRBs. I will discuss the simultaneous gamma-ray observations of multiple bursts with sub-millisecond time sampling and discuss the ongoing rapid optical program at VERITAS. We will present the simultaneous observations during bursts from FRB20180916B and ongoing campaigns with 6 other repeaters. Future work with imaging atmosphere Cherenkov telescopes and the implications for upgrades to the VERITAS camera will also be discussed.

KEYWORDS Gamma-ray, FRBs, Multi-wavelength, Optical, Photometry, Transients

IAUS 369
#2862

A Synthetic Pulse Injection System for the CHIME/FRB Experiment

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The detection pipeline in the Canadian Hydrogen Intensity Mapping Experiment Fast Radio Burst project (CHIME/FRB), like all FRB detection pipelines, is subject to selection effects. To correct for these, a synthetic pulse injection system was developed. The system injected a sample population comprised of ~85,000 synthetic pulses with ~25,000 corresponding detections for the First CHIME/FRB Catalog, and is now being modified to inject an order of magnitude larger sample. Such an increase in sample size will improve our understanding of CHIME/FRB's biases, and the true FRB population as a result. We present in detail the architecture of the injection system, and the methods with which it was operated for the First CHIME/FRB Catalog. We share some examples of the injection dataset's utility in understanding and correcting biases in the First CHIME/FRB Catalog, and discuss what further insights can be made with a larger injection sample. Finally, we discuss the utility of the injection system in improving CHIME/FRB's sensitivity.

KEYWORDS FRBs, CHIME

IAUS 369

#2578

Constraining the distribution of cosmic baryons from the FLIMFLAM survey

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Most of the cosmic baryons are expected to reside in the diffuse intergalactic medium (IGM) tracing the Cosmic Web or in the circumgalactic medium (CGM) of the galactic halos. Inferring the exact spacial distribution of the baryons between IGM and CGM will inform models of galaxy evolution and feedback mechanisms. The FRBs constitute a unique probe of this distribution, as their characteristic dispersion measure encodes the information about the amount of baryonic matter integrated along the line-of-sight. However, due to significant uncertainty caused by cosmic variance, it is estimated that the large sample (~103-4) of FRBs is required to make meaningful constraints. In order to overcome this problem and reduce the cosmic variance, we developed a fully Bayesian statistical algorithm that reconstructs the underlying matter density field based on the redshift positions of the galaxies in the foreground of the localized FRBs. Using the MCMC algorithm, we predict that a sample of just 30 FRBs will be enough to constrain the fraction of cosmic baryons in the IGM/CGM to unprecedented precision of ~5-10%. Finally, we show preliminary constraints based on the density reconstructions in the foreground of 8 FRBs, obtained by the dedicated FLIMFLAM spectroscopic survey.

KEYWORDS FRB, IGM, CGM

IAUS 369

#2382

A Fast Radio Burst Associated with a Binary Neutron Star Merger

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The mergers of compact objects has been suggested as the progenitors of the potentially non-repeating fast radio burst (FRB) population. We present an association between a once-off fast radio burst and a gravitational wave (GW) event. The product of temporal, spatial, and DM chance coincidence probabilities for the association is 1.9 × 10-4. In this talk, we discuss the properties of the FRB and GW events, the chance probability calculation, and how the association is consistent with a post-merger, supra-massive neutron or quark star emitting an FRB upon collapse to a black hole.

KEYWORDS Fast Radio Burst, Gravitational Wave, High Energy Astrophysics, Multimessenger Astrophysics

Beyond the Hubble Constant: further results from fitting the z-DM distribution of localised CRAFT FRBs

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A new sample of FRBs localised to their host galaxies by the CRAFT/F4 collaborations has recently allowed a new measurement of the Hubble Constant, H_0. This main result is being presented by Ghosh et al. The multi-parameter fit used to obtain this result however necessarily also includes the intrinsic FRB luminosity function, source evolution, and host galaxy contribution to the DM. While these may be nuisance parameters for H_0, they are intrinsically of great interest to the FRB community. In this recording, I'll discuss the results of these fits beyond H0, correlations between fitting parameters, and which aspect of the measurements (DM, fluence, z - if available - and the number of FRBs detected by different surveys) contributed the most information to which quantities. This guides future measurements and highlights any possible systematic errors. I'll also present predictions of the resulting model for the z,DM distribution for FRBs observed by other instruments such as FAST

KEYWORDS FRBs, CRAFT, Cosmology, Hubble Constant

IAUS 369

#2236

The Petabyte Project

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Transient radio sources, such as Fast Radio Bursts (FRBs), intermittent pulsars, and rotating radio transients, can offer a wealth of information regarding extreme emission physics as well as the intervening interstellar and/or intergalactic medium. Vital steps towards understanding the physics behind these objects include characterizing their source populations and estimating their event rates across observing frequencies. However, previous efforts have been undertaken mostly by individual survey teams at disparate observing frequencies and telescopes, and with non-uniform algorithms for searching and characterization. The Petabyte Project (TPP) aims to address these issues by uniformly reprocessing data from several Petabytes of radio transient surveys covering two decades of observing frequency (300 MHz-20 GHz). The TPP will provide robust event rate analyses, in-depth assessment of survey and pipeline completeness, as well as revealing discoveries from archival and ongoing radio surveys. We present an overview of TPP's processing pipeline, our available surveys and their sky coverage, and some preliminary results. The high observing frequency surveys available to us, as well as our processing pipeline's maximum search DM of 10,000 pc cm-3, allow us to potentially discover previously unseen classes of FRBs at high frequencies and high redshifts. We also examine the overlapping sky coverage available to us through multiple surveys, and estimate our ability to detect transient sources between them.

KEYWORDS Fast Radio Burst, transients, big data

IAUS 369
#2017

Constraining the DM Contributions of Large-Scale Structure

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The distribution of matter in the Universe results from interplay between gravitational collapse, cosmological expansion, and galactic feedback mechanisms. Thus a complete understanding of its large-scale structure (LSS) is desirable.

Cosmological simulations predict a web-like LSS, colloquially called the Cosmic Web. Specifically, this structure can be classified into subcomponents: halos, connected by filaments, separated by under-dense voids.

Currently, half of the Universe's expected baryon budget is easily observable, and understood to be tied up in mediums within (the ISM), around (the CGM), and between (the IGM, ICM) galaxies. The rest, though not yet easily observable, is predicted to inhabit a gravitationally shock-heated medium known as the WHIM, in turn predicted to inhabit filamentary structure in the Cosmic Web.

Recently, FRBs have verified the existence of these hidden baryons, but our understanding of their exact distribution is incomplete. Studies to detect filamentary structure (via tracers e.g. the thermal Sunyaev Zel'dovich effect) are underway. Studies to identify the CGM baryon fraction using FRBs have been proposed. 3D mass density reconstruction techniques (e.g. tidal tensors) may leverage future surveys cataloguing billions of galaxies (e.g. LSST) to reconstruct large volumes of LSS.

FRB DM measurements could augment such work, enabling in-depth understanding of the free electron distribution of the Universe. Thus, understanding the DM contributions of LSS is also desirable. Simulations may prove a useful tool for substantiating such work.

We are thus investigating the contributions to DM by LSS in IllustrisTNG. We have developed methods to classify LSS and identify impact factors to galaxies along FRB sightlines. We will discuss the evolution of LSS DM contributions with redshift, which may be compared with, e.g. estimated DM contributions of the WHIM. Early results suggest that the majority of DM is indeed tied up in filamentary substructure.

KEYWORDS FRB, DM, LSS, Cosmic Web, WHIM, Redshift, Cosmology

IAUS 369

#1929

Characterization of the first localized DSA-110 FRB sample- radio properties

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The Deep Synoptic Array-110 (DSA-110) is currently the only radio interferometer designed specifically for FRB searching and localization. It is expected to achieve a localization diameter of less than 3 arcseconds. This talk presents one of the series of papers that report the first sample of FRBs detected by DSA-64. Here, we report the radio properties of FRBs detected by DSA-64 until mid-2022. We explore the burst morphology using the high-resolution voltage data. We compare the radio features with the statistical properties of the larger FRB population. In particular, for those well-localized FRBs, we discuss the connection (or a lack of correlation) between their radio characteristics and the properties of their host galaxies, providing new insights into the origin of this phenomenon.

KEYWORDS radio interferometer, localization

IAUS 369
#1845

CHIME/FRB Outriggers: A New Array for a New Era of FRB Research

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The Canadian Hydrogen Intensity Mapping Experiment (CHIME) telescope has detected thousands of fast radio bursts (FRBs) with its dedicated transient-search backend (CHIME/FRB). CHIME/FRB is now expanding to include a very long baseline interferometry (VLBI) array of transcontinental outrigger stations with the goal of localizing every detected burst to ~50 milliarcsecond precision. In addition to host galaxy identification and redshift estimates, this level of localization precision within the host will enable us to constrain the origins and host environments of FRBs, and enable robust cosmology with their properties. Leveraging novel calibration techniques developed by our CHIME/FRB team, the Outrigger array will mark a paradigm shift in FRB research. In this talk, I will motivate the Outrigger project and its goals, discuss how we are overcoming the challenges of low-frequency VLBI, and share recent results from the first Outrigger to come online.

KEYWORDS FRB, VLBI, localization, CHIME

IAUS 369

#1821

The Canadian Hydrogen Observatory and Radio transient Detector

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The Canadian Hydrogen Observatory and Radio transient Detector (CHORD) is a next-generation instrument designed to succeed the Canadian Hydrogen Intensity Mapping Experiment (CHIME) as the world-leading facility for fast radio burst science. CHORD will consist of a compact core of 512 6-meter composite dishes instrumented ultra-wideband feeds and receivers sensitive to the 300-1500 MHz band. Two 64-dish outrigger stations at continental baseline distances will complement the core array, providing sub-arcsecond transient localization. CHORD is now reaching the final stages of design and validation of enabling technologies. In this talk I will present the CHORD program and report on the current status.

KEYWORDS CHORD, CHIME, interferometer, localization

Astronomy for All
Busan 2022

IAUS 369

#1816

Potential Analogs of the First Repeating Fast Radio Burst

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The first precise localization of a fast radio burst (FRB) to a low-luminosity, dwarf host galaxy led to the discovery of a persistent radio source (PRS) coincident with the position of the bursts and offset from the host center. This combination of properties has motivated theories suggesting that FRBs are powered by magnetars born in superluminous supernovae (SLSNe) or long-duration gamma-ray bursts (LGRBs). A prediction of this model is that compact radio sources offset from the centers of dwarf galaxies may reveal the locations of at least some FRBs. Indeed, the detection and localization of the repeating FRB20190520B marks the second association with a PRS in a dwarf host galaxy. Recently, Reines et al. presented the discovery of 12 compact radio sources in dwarf galaxies offset from the galactic center using high-resolution VLA observations. They argued that the sources originate from a group of accreting wandering massive black holes. However, their similarity to the repeating FRB PRSs suggests that they may instead share a common origin with FRBs. We explore this possible association using multi-frequency VLA observations of all 12 radio sources. Specifically, we compare the spectral energy distributions of the radio emission to models of central-engine powered emission (in analogy with FRBs) and accreting black holes. This analysis allows us to determine whether these radio sources stem from magnetar nebulae or off-axis LGRB afterglows, analogous to the first repeating FRB (FRB121102). Our work will play a critical role in exploring the possibility that these sources emerge from the same population, potentially leading to the discovery of the first large sample of analogs to FRB121102.

KEYWORDS Fast Radio Bursts, Magnetars, Gamma-ray Bursts, Active Galactic Nuclei

IAUS 369
#1774

Fast Radio Burst Flux Calibration with CHIME

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Fast radio bursts (FRBs) are bright radio transients of micro-to-millisecond duration and unknown extragalactic origin. Central to the mystery of FRBs are their extremely high characteristic energies, which surpass the typical energies of other radio transients of similar duration, like Galactic pulsar and magnetar bursts, by orders of magnitude. Calibration of FRB-detecting telescopes for burst flux and fluence determination is crucial for FRB science, as these measurements enable studies of the FRB energy and brightness distribution in comparison to progenitor theories. The Canadian Hydrogen Intensity Mapping Experiment (CHIME) is a radio interferometer located near Penticton, B.C., that has detected an unprecedented number of FRBs. The efficiency with which CHIME detects these bursts is enabled by its novel design, consisting of four 20-m by 100-m cylindrical reflectors with 256 dual-polarization feeds lined along each axis that are sensitive to a wide bandwidth of 400-800 MHz. Such a novel design also produces novel challenges for CHIME/FRB flux calibration. In this talk, I provide a review of these challenges, as well as an automated flux calibration software pipeline that was developed to calibrate bursts detected in the first CHIME/FRB catalog, consisting of 536 events detected between July 25th, 2018 and July 1st, 2019.

KEYWORDS fast radio bursts, radio astronomy, calibration

IAUS 369
#1688

Identifying FRB repeater candidates with CHIME/FRB using unsupervised machine learning

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The CHIME/FRB collaboration detects Fast Radio Bursts (FRBs) daily. Over the course of the survey, we have published ~20 repeating FRBs (CHIME/FRB 2019, Foncesca et al. 2020, Lanman et al. 2021, Bhardwaj et al. 2021). In addition, we have published 474 apparently non-repeating FRBs in our first FRB catalog. Given the large number of FRBs being detected by CHIME/FRB, identifying true repeaters versus chance coincidences has become a challenge. To address this, we have implemented a systematic method to identify repeaters based on DBSCAN, an unsupervised machine learning algorithm. Our algorithm uses only basic detection properties like sky location and dispersion measure and is thus fast and efficient. We employ our algorithm on the CHIME/FRB sample from late 2019 to mid 2021. The results more than double the current population (an accompanying discussion of these sources is submitted in Dr Ziggy Pleunis's abstract).

In this talk, I will present the algorithm and the nuances of working with CHIME/FRB data. I will also discuss further applications of the algorithm.

KEYWORDS FRB, Repeaters, Repeat, CHIME, Machine learning, DBSCAN, ML

IAUS 369
#1685

Forecast of upcoming FRB surveys and the potential of cosmological applications

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FRBs are promising tools for various cosmological and astrophysical tests. These include finding the missing baryons and locating the ionized matter in the intergalactic medium, constraining cosmological parameters, detecting the epochs of reionization, constraining the photon mass, and more. Many of these applications need FRBs with known redshifts. These redshifts have to be obtained through optical followup observations of FRBs with arcsecond localization. This requires a lot of telescope time and is the likely bottleneck in upcoming FRB surveys. In this talk I present our forecast of FRB populations that will be observed by future telescopes including the CHIME, ASKAP, and SKA. We assign host galaxies from the GALFORM simulation and check their detectability in current and future optical surveys including SDSS and LSST. The limited sensitivity of the optical surveys has consequences on the redshift distribution of localized FRBs and therefore on FRB applications. To give examples, we look at the effects on two applications, namely the location of the missing baryons and constraints of the photon mass. Finally we discuss optimized strategies for optical followup observations of galaxies that are not covered in optical surveys.

KEYWORDS fast radio bursts, large-scale structure of Universe, cosmological parameters

IAUS 369
#1283

FRB Host Galaxy Modeling with Prospector

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Recent surveys such as CRAFT using the Australian Square Kilometre Array Pathfinder (ASKAP) have allowed for sub-arcsecond localization of an FRB with its host galaxy, making studies of FRB host galaxies a viable way to learn more about these events. I will discuss how stellar population synthesis modeling of FRB host galaxies using non-parametric star formation histories can be used to constrain progenitor models. I will also present fits of all localized FRB host galaxies to date using the SED modeling code, Prospector, and discuss their implications.

KEYWORDS Fast radio bursts, Host galaxies, Galaxy modeling, Stellar population synthesis

IAUS 369
#1153

Multipath propagation of FRBs as a tool for uncovering the properties of extragalactic plasma

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The interaction of FRB radio waves with the intervening plasma between us and the sources is viewed, at times, as a nuisance for probing intrinsic FRB properties. At the same time, it offers unique ways to probe interstellar matter at large redshifts and the intervening intergalactic medium. In particular, due to multi-path propagation, a magnetized plasma screen can cause temporal broadening of the FRB, lightcurve variability, spectral decoherence, depolarization and induced circular polarization. I will describe how these different properties are directly inter-related, how they manifest in FRB observations and how this can already be used to constrain the nature of the intervening plasma in some bursts. Finally, I will also describe how intervening plasma screens would affect gravitational lensing events of cosmological FRBs.

KEYWORDS fast radio bursts, polarization, radio continuum: transients, gravitational lensing, ISM: structure

New repeating sources of FRBs from CHIME/FRB

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The CHIME/FRB project has so far discovered twenty sources of repeating FRBs, which has directly and through targeted follow-up observations led to many advances in our understanding of FRBs. We present an updated sample of repeating sources of FRBs discovered from late 2019 to mid 2021. In order to uniformly search our events for repeating sources, we employed a clustering algorithm on all events in our database. The new repeaters identified this way more than double the number of known repeaters, providing new targets to follow up and a much larger sample for comparisons with apparent non-repeaters. I will present the new sources, our repeater detection rate over time and updated population comparisons.

KEYWORDS Fast radio bursts, Sources of repeating FRBs, Surveys

IAUS 369
#1058

A Highly Variable Magnetized Environment in a Fast Radio Burst Source

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Fast radio bursts are brief, intense flashes of radio waves that arise from unknown sources in galaxies across the universe. Observations of the polarization properties in repeating fast radio bursts have shown they can reside in highly magnetized environments, such as in the immediate vicinity of a recent supernova or massive black hole. We have observed the actively repeating FRB 20190520B over a span of fourteen months and found that its Faraday rotation measure is both large in magnitude and rapidly varying, including two sign changes which indicate time-dependent orientation changes of the magnetic field along our line of sight. The FRB also depolarizes rapidly at lower frequencies. These phenomena can be explained in terms of multipath propagation through a highly turbulent, dense magnetized screen. We constrain the distance to such a screen using our model, thereby distinctly narrowing the possible physical configurations that could give rise to the emission seen in FRB 20190520B.

KEYWORDS Fast Radio Bursts, Polarization, Rotation Measure

IAUS 369
#861

GMRT Mapping of HI 21cm emission from an FRB host galaxy: A fast radio burst progenitor born in a galaxy merger

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Although more than 500 fast radio bursts (FRBs) have been discovered so far, the origins of FRBs and the nature of the FRB progenitors remain mysteries today. Studies of FRB environments are critical to understand the physical conditions that give rise to the FRB progenitors. I will describe Giant Metrewave Radio Telescope (GMRT) HI 21cm observations of the host galaxy of the repeating burst FRB 20180916B, at z~0.034, the first HI 21cm mapping of an FRB host galaxy. We find that the FRB host is an HI-rich but quiescent galaxy, indicating that it has recently acquired gas via either accretion or a minor merger. We find the HI distribution to be highly disturbed, with an HI hole in the north-east of the galaxy, extended HI emission outside the optical disk, and a high HI column density close to the FRB position. The FRB host is part of a group environment with HI 21cm emission detected from four companion galaxies, with the closest one located at a projected distance of ~22 kpc. Our HI 21cm images indicate that the FRB host galaxy has recently undergone a minor merger with another galaxy, that disturbed the HI in the galaxy disk and compressed the HI near the FRB location, increasing the HI column density here. This is likely to have caused a burst of star-formation in the outskirts of the galaxy, that gave rise to the FRB progenitor.

KEYWORDS Galaxies, HI 21cm emission, Fast Radio Bursts

IAUS 369
#769

A method for reconstructing the Galactic magnetic field using fast radio bursts and radio galaxies

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With the rapid increase of fast radio burst (FRB) detections within the past few years, there is now a catalogue being developed for all-sky extragalactic dispersion measure (DM) observations in addition to the existing collection of all-sky extragalactic Faraday rotation measurements (RMs) of radio galaxies. We present a method of reconstructing all-sky information of the Galactic magnetic field component parallel to the observer, B||, using simulated observations of the RM and DM along lines of sight to radio galaxies and FRB populations, respectively.

This technique is capable of identifying small variations in the input Galactic magnetic field and thermal electron density models. Significant extragalactic contributions to the DM are the predominant impediment in accurately reconstructing the Galactic DM and <B||> skies. We look at ways to improve the reconstruction by applying a filtering algorithm on the simulated DM lines of sight and further derive generalized corrections for DM observations at |b| > 10 degrees that help to disentangle Galactic and extragalactic DM contributions.

Overall, we are able to reconstruct both large-scale Galactic structure and local features in the Milky Way's magnetic field from the assumed models and present broadly applicable techniques for separating Galactic and extragalactic DM components in FRB observations. We discuss the application of this technique to future FRB observations and address possible differences between our simulated model and observed data, namely: adjusting the priors of the inference model, an unevenly distributed population of FRBs on the sky, and localized extragalactic DM structures.

KEYWORDS Fast radio bursts, Galactic magnetic field, Galaxy structure, Radio polarization, Radio galaxies

IAUS 369
#657

Simultaneous Multi-Wavelength Observations (Gamma, X-ray, UV, Optical, and Radio) of Two FRBs

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Despite the frequency and high energy output of FRBs, what causes these bursts have eluded astronomers since their discovery over a decade ago. Information on emission coherent with the radio burst in other wavelengths can help reveal the physical processes that create these bursts. I present the desgn and results from an observational program that can do this called the Deeper Faster Wider (DWF) program. A key part of the DWF program is coordinating ~10 multi-wavelength observatories to perform deep, wide-field, fast cadence observations on the same field simultaneously to collect possible imaging on fast-evolving transients before they fade. Importantly, DWF can collect data before, during and after fast transients. Typically, a DWF observing run goes for a week. In particular, I present results from DWF operation run 8 (DWF-O8, September 2022). During DWF-O8, two FRBs were detected with the Murriyang Radio Telescope (formerly known as the Parkes Radio Telescope). Simultaneously observing with Murriayng was the Neil Gehrels Swift Observatory, Hard X-ray Modulation Telescope, AstroSat, the Korea Microlensing Telescope Network, the Huntsman Telescope, Murriyang and the Molonglo Observatory Synthesis Telescope, amongst others.

KEYWORDS multi-wavelength, FRB, radio, optical, high energy

IAUS 370
Winds of Stars and Exoplanets

Invited & Contributed Talks

IAUS 370

#2751

Observations of winds and CMEs of low-mass stars

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There has been a resurgence of interest in the last several years in understanding mass loss from stars in the cool half of the HR diagram. This has been stimulated by two not quite separate activities: an increase in observational capability to potentially detect transient and steady signatures of stellar mass loss, and an interest in understanding the conditions that a star creates in its near-stellar environment which exoplanets experience. This is a multi-wavelength and cross-discipplinary endeavour. I will summarize recent results pointing out the complexity in the stellar mass loss menagerie, ranging from recent results on steady winds and transient mass loss, the connection of stellar flares to CMEs, and emerging complexities in understanding flare energy partitions.

KEYWORDS stars, winds, flares, CMEs

IAUS 370
#1806

FUV Constraints on the Winds and Rotation of Main-Sequence O Stars at Extremely Low Metallicity

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Low-metallicity massive stars shape the evolution of dwarf galaxies in the local universe and young galaxies at high redshift. Theory predicts that these stars drive weaker winds with lower mass-loss rates than their higher-metallicity counterparts, with important implications for stellar evolution, feedback, and ionizing photon production. However, few observations of individual, metal-poor OB stars exist to validate widely adopted models of stellar winds due to the large distance of even the closest galaxies more metal-poor than the Small Magellanic Cloud (20% Z_sun). We present new medium-resolution HST/COS FUV spectra of three late-O dwarf stars in the metal-poor galaxies WLM (14% Z_sun), Sextans A (6% Z_sun), and Leo P (3% Z_sun). The FUV spectra reveal a clear metallicity dependence in the strengths of photospheric metal lines and wind features. We characterize the photospheric metal opacities, projected rotation speeds, and strength of wind features sensitive to mass loss. We find that the two most metal-poor stars both have weak wind features and are rotating faster than 290 km/s, consistent with the prediction that metal-poor stars with low mass-loss rates inefficiently lose angular momentum during their main-sequence lifetimes. These new observations provide theorists with a novel, empirical constraint on the connection between the stellar winds and rotation of O dwarf stars at extremely low metallicity.

KEYWORDS

IAUS 370
#828

Slingshot Prominences, Formation, Ejection and Cycle Frequency in Cool Stars

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Stars lose mass and angular momentum during their lifetimes. Observing exactly how low-mass stars undergo this process is challenging as the mass of their winds are tenuous. However, low mass stars such as M-dwarfs typically have magnetically dominant outer atmospheres, leading to the development of prominent plasma structures suspended in their outer corona. Observations of H-alpha absorption of a number of low mass stars, show prominences transiting the stellar disc and being ejected into the extended stellar wind. Analytic modelling has shown that these M-dwarf coronal structures can grow to be orders of magnitude larger than their solar counterparts. This makes prominences responsible for mass and angular momentum loss comparable to that due to the stellar wind. We present results from a numerical study which used magnetohydrodynamic simulations to model the balance between gravity, magnetic confinement, and rotational acceleration. This allows us to study the time dependent nature of prominence formation. We demonstrate that a prominence, formed beyond the co-rotation radius, is ejected into the extended stellar wind in the slingshot prominence paradigm. Mass, angular momentum flux and ejection frequency have been calculated for a representative cool star, in the so called Thermal Non-Equilibrium (TNE) regime.

KEYWORDS prominence, cool stars, magnetosphere, simulation

New empirical mass-loss rates and wind properties of massive stars at low metallicity

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Hot, massive stars are known to host unstable, radiation-driven outflowing winds, giving rise to dense clumps of material which severely affect the diagnostic techniques used to derive wind properties of massive stars. Most of the current diagnostic models account for wind inhomogeneities by assuming a one-component medium consisting of optically thin clumps, and maintaining a smooth velocity-field. However, this neglects important light-leakage effects through porous channels in-between the clumps. We have recently incorporated these light-leakage effects into our stellar atmosphere modelling code FASTWIND, and here we will present quantitative mass-loss results from a combined Ultraviolet-Optical wind analysis of 40 O-stars across the Galaxy, LMC and SMC. Using a genetic-algorithm fitting-approach, we investigate the impact the wind physics has on derived stellar and wind parameters, and how this depends on metallicity and spectral type. These results also provide an excellent base to expand upon with upcoming large surveys, such as (XSH-)ULLYSES which will provide optical data to complement the (HST-)ULLYSES UV survey for a sample of 250 OB stars at low metallicity. By applying the method presented here to such a sample we will be able to establish trends between wind properties and fundamental stellar parameters on an unprecedented scale. As the ULLYSES UV spectra are already available, we will also present results for terminal wind speeds measured from saturated P-Cygni UV line profiles. These results, when combined with previous studies on Galactic samples, allow us to obtain new empirical estimates of the metallicity dependence of terminal wind speeds.

KEYWORDS early-type stars, massive stars, stellar winds, mass loss, spectroscopy, stellar atmospheres

IAUS 370
#283

The effect of winds in Red Supergiants I. 1D Modelling for interferometric observations

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Red supergiants (RSGs) are evolved massive stars in a stage preceding core-collapse supernova. Understanding evolved-phases of these cool stars is key to understanding the cosmic matter cycle of our Universe, since they enrich the cosmos with newly formed elements. However, the physical processes that trigger mass loss in their atmospheres are still not fully understood, and remain one of the key questions in stellar astrophysics. In this talk, we propose a new 1D method to study the extended atmospheres of these cold stars, studying the effect of a stellar wind for both a simple radiative equilibrium model and a semi-empirical model based on Harper et al. (2001). We then can compute the intensities, spectral energy distributions (SEDs) and visibilities matching the observations for the different instruments in the Very Large Telescope Interferometer (VLTI). Specifically, I will discuss the robustness of our results when comparing with the atmospheric structure of AH Sco, UY Sct and KW Sgr based on published VLTI/AMBER data. We find that our model can accuratelly match these observations, showing the enormous potential of this methodology to reproduce extended atmospheres of RSGs.

KEYWORDS supergiants, massive stars, mass loss, interferometry, stellar atmospheres, stars: evolution, stellar winds

Observations of outflows of massive stars

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Mass loss plays a key role in the evolution of massive stars and their environment. High mass-loss events are traced by complex circumstellar ejecta (nebulae) and intricate line profiles across the upper HR diagram for massive stars in different evolutionary stages. Although the basic physics of radiation-driven stellar wind is well understood, the driving mechanisms for sudden enhanced mass loss and related instabilities are still debated. In this review, the mass loss characteristics and the possible mechanisms will be surveyed for an observational set of prominent massive star groups that experience strong stellar winds and periods of enhanced and eruptive mass loss; the Luminous Blue Variables, warm and cool hypergiants, B[e] supergiants, Wolf-Rayet stars, OB stars and supergiants, and supernova impostors.

KEYWORDS winds, circumstellar matter, outflows, variables, evolution, emission-line

IAUS 370

#2775

Mass-loss rates of cool evolved stars in the Local Group galaxies

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The final stages of stellar evolution are critical for the evolution of galaxies because the processed matter is returned to the interstellar medium (ISM). Furthermore, the feedback from cool evolved stars is in the form of dust grains that play an important role in the temperature regulation of ISM, chemistry and formation of planets. To begin, to understand the mass-loss mechanism we: [1] carried out a census of cool evolved stars in the majority of Local Group galaxies via long-term monitoring surveys in optical and near-IR wavelengths [2] performed accurate modelling of spectral energy distribution (SEDs) in order to measure the excess infrared emission from dust produced by these stars, and to quantify the amount of matter they return to the interstellar medium. In this paper, I first present the mass-loss rates of cool evolved stars in wide ranges of masses to see how mass loss mechanism acts in different populations (RGBs, AGBs (M-type or carbon stars) and RSGs) and to investigate whether it differs in different environments. Then, I will discuss the ISM replenishment by mass-loss via cool evolved stars in different galaxies.

KEYWORDS stars: mass-loss, stars: AGB and post-AGB, stars: carbon, supergiants, galaxies: individual

IAUS 370
#1595

A review on the observations of planetary winds and outflows

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We have recently hit the milestone of 5,000 exoplanets discovered. In a stark contrast with the Solar System, most of the exoplanets we know to date orbit extremely close to their host stars, causing them to lose copious amounts of gas through atmospheric escape at some stage in their lives. In some planets, this process can be so dramatic that they shrink in timescales of a few millions to billions of years, imprinting features in the demographics of transiting exoplanets. Depending on the transit geometry, ionizing conditions, and atmospheric properties, a planetary outflow can be observed using transmission spectroscopy in the ultraviolet and near-infrared. In this review, I will go over the first observations and evidence of atmospheric escape in the Solar System, and discuss the discoveries of evaporating planets outside the Solar System. I will give a special attention to the different techniques used to make these observations, their respective advantages and disadvantages. I will also briefly discuss the impact of atmospheric escape in the evolution of small exoplanets, and how we plan to test our hypotheses using observations in the coming future.

KEYWORDS exoplanets, atmospheres, space weather, atmospheric escape, outflows

IAUS 370

#2096

The porous envelope and circumstellar wind matter of the closest carbon star

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Many pre-planetary nebulae (PPNe) consist of newly-formed inner bipolar/multipolar lobes and outer spirals/rings/arcs that are the fossil records of the stellar wind matter accumulated during the asymptotic giant branch (AGB) phase. The coexistence of such morphologically distinct circumstellar structures is a mystery; however, it is widely believed that binaries play a key role. The clue to resolve the mystery of the shape transition along the stellar phase evolution may be offered, most directly, at the moment that an AGB star is evolving off toward the PPN phase.

Recent dramatic changes of the closest carbon star CW Leo, found in the optical to infrared observations, likely indicate that we are witnessing the moment of transition between these late stellar evolutionary phases. The new appearance of a red compact brightness peak at the predicted stellar position is possibly an unveiling event of the star, and the radial beams emerging from the stellar position resemble the feature of the PPN Egg Nebula. Anisotropic wind expansion is deduced from the analysis on the differential proper motion of multiple circular threads imprinted in the stellar wind matter, implying the presence of an eccentric-orbit binary at the center. The increase of light curve over two decades is also extraordinary, and it is possibly related to the phase transition. Decadal-scale variations are further found in the residuals of light curves, in the relative brightness of radial beams, and in the extended halo brightness distribution. All these features are viewed in the context of the stellar light illumination through the porous (clumpy) inner envelope of the carbon star at the tip of AGB, from which we desire to understand the condition for evolutionary phase transition.

KEYWORDS Evolved star (AGB/PPN), Circumstellar medium, Stellar wind

IAUS 370
#2281

Updates on recent findings from the solar wind with major facilities

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Since more than sixty years the solar wind has been monitored and modelled in order to understand its formation, acceleration process and its interaction with the atmosphere of the planets. In these decades we have made important progress in the understanding of this phenomenon, even though several questions remain opened. For instance, the assessment of connection between the in situ measures of the wind and the source regions at the Sun is extremely difficult. This is because until recently all the measures were made from 1 AU: the wind parcel measured in situ have the time, during the travel through the heliosphere, to interact with the ambient environment and modify its properties at the source; the remote sensing observations have a limited spatial resolution to identify the regions and the processes at the origin of the nascent wind. Moreover, we had to rely on a single line of sight or point of measure.

The situation has changed in the last five years, when Solar Parker Probe and Solar Orbiter satellites have been lunched. Their orbits allow a close view of the Sun (a zooming effect on the wind source regions for Solar Orbiter) and in situ measures of the nascent solar wind. Furthermore, multi-point of view measures are now accessible together with the already existing other laboratories.

In this talk, I will review and discuss the latest findings from the observations with the new and existing observatories. I will also highlight the new opportunities they are offering to infer the Sun-heliosphere connectivity and to better constrain the winds modelling.

KEYWORDS Sun, UV, in-situ

IAUS 370

#2278

Effect of stellar coronal mass ejections and flares on the atmosphere of hot Jupiters and their transit signatures

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The evolution of planetary atmospheres is very much dependent on the environment of their host stars (e.g., stellar radiation, stellar wind, stellar flares, and Coronal Mass Ejections (CMEs)).

For close-in planets, the stellar radiation evaporates the planetary atmosphere as a form of supersonic planetary outflow due to photoionization. This planetary outflow further interacts with the stellar wind, which shapes up the planetary atmosphere (sometimes producing a comet-like structure)

and its mass-loss rate. Moreover, flares and CMEs from the star will also have a great impact on planetary evaporation. In this talk, I will discuss the effect of stellar wind, and the impact of flares and CMEs on the atmosphere of hot Jupiters using a self-consistent 3D radiation hydrodynamic model. Among all the considered stellar environments, we find that CMEs are very effective in eroding planetary atmospheres. We also calculate synthetic Lyman-alpha transit signatures and find that the flare alone cannot explain the observed high blue-shifted velocities seen in the Lyman-alpha observation. The CME, however, leads to an increase in the velocity of the escaping atmosphere, enhancing the transit depth at high blue-shifted velocities.

KEYWORDS Star-planet interaction, planetary outflow, stellar cmes and flares

Is the magnetospheric accretion process active in Herbig Ae/Be stars ?

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Herbig Ae/Be stars (HAeBes) are young intermediate mass objects that share properties with low mass T Tauri stars (TTs) despite having different stellar masses and internal structures. Both groups exhibit similar ages, infrared and ultraviolet excesses above the photosphere, and signs of magnetic activity, and some display P Cygni absorption features that originate in strong collimated winds. In spite of lacking outer convective zones, essential to power a solar-type dynamo, a small fraction of HAeBes exhibit dipolar magnetic fields with similar strengths to those observed in Ap/Bp main-sequence stars. Due to later are slow rotators with rotational periods ranging from days to decades, it has been claimed that HAeBes are progenitors of Ap/Bp stars. However, recent findings have confirmed that Ap/Bps do not undergo significant angular momentum losses during the main-sequence life, therefore, the stellar spin-down must be in action either before or at the beginning of the main sequence stage. We selected an approximately coeval sample of both TTs and HAeBes belonging to the subgroups of the Orion OB1 association, together with 23 Ap/Bp stars to study the interplay between rotation, accretion, stellar winds and magnetic field strengths by using a spin evolution model together with rotational measurements. We find a dramatic decrease of angular momentum in Ap/Bps with age that could be explained in terms of angular momentum loss via stellar winds powered by accretion.

KEYWORDS Star Formation, Stellar Winds, Accretion disks, Stellar Rotation

IAUS 370

#335

INTERPRETATION OF TRANSIT ABSORPTIONS IN THE ATMOSPHERE OF HD-189733b

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Hot exoplnets are heated by intense radiation of the host star result in intensive thermal escape and mass loss of their hydrogen-dominated upper atmospheres. Spectral absorptions of hot exoplanets passing through stellar disk plays an important role in investigation of exoplanetary atmospheres, providing information on these plasmaspheres such as composition, temperature, density, chemical and physical processes that occur at interaction of planetary streams with the stellar wind.

Many hot exoplanets consist mostly of hydrogen, and the Ly-a spectral line is valuable for providing evidence of atmospheric escape. However, it is strongly absorbed in interstellar medium and contaminated by geocoronal emission. As it was suggested in [1], the absorption by a metastable helium in the 23S state at 10830 Å offers an alternative way to probe the evaporating exoplanetary atmospheres. It is not affected by the interstellar medium and can be observed by ground telescopes with high resolution.

A 3D gas-dynamic model which takes into account the processes of recombination and plasma-photochemistry of plasma components [2, 3] was used in this work to reproduce the transit absorptions in metastable helium 10830 A line of the planet HD-189733b to obtain the best fit to the observational data. As a result, the most probable atmospheric parameters for the case of HD-189733b planets have been determined.

KEYWORDS Hot Jupiters, HD-189733b, space plasma, transit spectroscopy

IAUS 370

#2585

X-ray observations as a tool to estimate stellar mass losses

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Stellar winds play a very important role for planetary habitability driving non-thermal losses and affecting the atmospheres' evolution (e.g., Gronoff et al. 2020). Despite their importance, stellar winds or mass loss rates of main sequence stars are very difficult to measure directly. There exist a number of indirect methods to estimate the mass loss rates of main sequence stars such as estimates based on spin-down of stellar rotation (e.g., Johnstone et al. 2015), radio observations (e.g., Fichtinger et al. 2017), transit observations of exoplanets in the Lyman-alpha line (Kislyakova et al. 2014, Vidotto & Bourrier 2017). A more direct method of measurements of mass loss rates is based on studying the astrospheric absorption in the Lyman-alpha line (e.g., Wood et al. 2002, 2005). In this method, the mass loss rate is estimated based on the additional absorption of the stellar Lyman-alpha emission. Such additional absorption arises due a population of energetic neutral hydrogen atoms produced by charge-exchange between stellar wind protons and neutrals in the interstellar medium (ISM) surrounding the star.

In this abstract, we discuss a similar method of estimating the mass loss rates of main sequence stars. When ionized stellar wind collides with the neutral ISM surrounding the star, highly charged ions of the wind (e.g., O7+, O6+, C5+, Ne8+, and others) charge exchange with the neutrals of the ISM and emit soft X-rays with very distinct spectral signatures as a result of this interaction. This mechanism (Solar/Stellar Wind Charge Exchange, SWCX) is known to generate soft X-ray emission on comets (e.g., Cravens 2002) and solar system planets (e.g., Bhardwaj et al. 2007). Here, we present the results of the search for the SWCX signatures in the XMM spectra of nearby stars and discuss potential signatures of the SWCX mechanism originating from stellar astrospheres.

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KEYWORDS stellar winds, observations, X-rays

IAUS 370
#1214

The origin of planetary winds

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Planetary wind, or atmospheric escape, is a fundamental phenomenon shaping the structure and evolution of planetary atmospheres. Being theoretically predicted for exoplanets long before its observational confirmation, atmospheric escape is a multiphysics and multiscale process. Physics of planetary winds range from global processes such as tidal interactions with the host star for planets at close-in orbits, through large-scale hydrodynamic outflow powered by the stellar high-energy radiation or the cooling luminosities of planets themselves, to essentially microphysical kinetic effects, including Jeans-like escape and the interaction of planetary atmospheres with stellar winds and the own magnetic fields of planets. Each of these processes is expected to be most relevant for planets of different properties and at different stages in planetary and stellar evolution. Thus, it is expected that the hydrodynamic outflow guides the evolution of hydrogen-dominated atmospheres of planets having low masses (below that of Neptune) and/or close-in orbits, while the kinetic effects are most important for the long-term evolution of planets with secondary atmospheres, similar to the inner planets in the Solar System. Finally, each of these processes is affected by the interaction with stellar winds.

Due to the favorable observational conditions, atmospheric escape signatures were first detected at hot Jupiters, giant planets orbiting in close proximity to their host stars. However, with the improvement of observational techniques, strong planetary winds can now be studied for smaller planets in more distant orbits (warm Neptunes) using high-resolution spectrometry in the ultraviolet and in the infrared. This provides a possibility of testing existing physical models and opens new questions calling for theoretical explanation.

KEYWORDS planetary winds, upper atmospheres, atmospheric escape

IAUS 370
#2626

Coronal Mass Ejections and Type II Radio Emission Variability during a Magnetic Cycle on the Solar-type Star ϵ Eridani

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We simulate possible stellar coronal mass ejection (CME) scenarios over the magnetic cycle of ϵ Eridani. We use three separate epochs from 2008, 2011, and 2013, to estimate the radio emission frequencies associated with these events. These stellar eruptions have proven to be elusive, although a promising approach to detect and characterise these phenomena are low-frequency radio observations of potential type II bursts as CME induced shocks propagate through the stellar corona. Stellar type II radio bursts are expected to emit below 450 MHz, similarly to their solar counterparts. We show that the length of time these events remain above the ionospheric cutoff is not necessarily dependent on the stellar magnetic cycle, but more on the eruption location relative to the stellar magnetic field. We find that these type II bursts would remain within the frequency range of LOFAR for a maximum of 20-30 minutes post-eruption for the polar CMEs, (50 minutes for 2nd harmonics). We find evidence of slower equatorial CMEs, which result in slightly longer observable windows for the 2008 and 2013 simulations. Stellar magnetic geometry and strength has a significant effect on the detectability of these events. We place the CMEs in the context of the stellar mass-loss rate (27–48 × solar mass-loss rate), showing that they can amount to 3-50% of the stellar wind mass-loss rate for epsilon Eridani. Continuous monitoring of likely stellar CME candidates with low-frequency radio telescopes will be required to detect these transient events.

KEYWORDS Stellar winds, Coronal Mass Ejections, MHD, Stellar activity

IAUS 370

#848

Theory and Diagnostics of hot star mass loss

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Massive stars have strong stellar winds that direct their evolution through the upper Hertzsprung-Russell diagram and determine the black hole mass function. Secondly, wind strength dictates the atmospheric structure that sets the ionising flux. Thirdly, the wind directly intervenes with the stellar envelope structure, which is decisive for both single star and binary evolution, affecting predictions for gravitational wave events. I discuss the current status of the line-driven wind theory including Monte Carlo and co-moving frame computations, as well as observational tests with large data-sets from the VLT and HST, in particular the XShooting ULLYSES (XSHOOTU) project.

KEYWORDS winds, mass loss, massive stars, evolution

The classification of the atmospheric escape: three types of escape driven by EUV photoionization heating

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The intense radiation from the host star can heat the upper atmosphere and drive the escape in close-in planets. The photoionization heating of hydrogen atoms by Extreme-Ultraviolet (>13.6 eV, EUV) has been considered as a dominant heating process, and many radiation hydrodynamic simulations have been performed. The simulations showed that the energy-conversion efficiency in the case of strong EUV flux becomes lower than the energy-limited, where the injected photo-energy mostly goes into the gas kinetic plus thermal energy. In the case of the strong EUV flux from the host, the flow is so-called recombination limited and the most of the EUV power is lost to the radiation cooling. However, the underlying physics that separates these two regimes is unclear. It is important for understanding the physics of close-in planets that could potentially show the signs of atmospheric escape regardless of whether Ly-alpha absorption has been undetected to date.

We find that the EUV-driven escape can be classified into three regimes according to the following two conditions. The first condition is that the photoheating timescale is equal to the gravitational timescale, which is related to the gravitational deceleration reducing the escape. The second is the condition where the characteristic temperature is equal to the equilibrium temperature determined by the heating and cooling. This condition determines whether the photoheating is rapid enough to heat the gas to the equilibrium temperature. We can classify the escape into three regimes using these two conditions and define the critical EUV flux. We find that the close-in planets with non-detection of Ly-alpha are exposed to smaller EUV flux than the critical flux (e.g. Pi Men c). However, K2-25 b may experience strong escape due to the intenser radiation than the critical flux and the Ly-alpha is still undetected. Our condition can classify the Ly-alpha non-detected planets into the strong mass-loss regime and weak regime by physical criterion. In this talk, we also discuss the results of the radiation hydrodynamics simulations of some observed close-in planets.

KEYWORDS Hot Jupiter, hydrodynamics, Atmosphere, Simulation

IAUS 370
#1392

`Discrete Absorption Components' from 3-D spot models of hot star winds

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Winds from hot, massive OB stars are driven by scattering and absorption of the stellar radiation by spectral lines. Along with the wind driving comes a plethora of wind variability, both on large and small spatial scales. A particular case of such wind variability occurring on large spatial scales are the so-called 'discrete-absorption components' (DACs). These DACs are ubiquitous among the sample of OB stars and manifest themselves by their migration through the absorption trough of resonance UV lines – from line centre to line edge – that is seen in time series of UV spectra. The outward moving density features are interpreted as large-scale density structures akin to co-rotating interaction regions in the solar wind. The observations also suggest that the DACs have a recurrence time scale that is intimately correlated with the (projected) stellar rotation. Therefore, there is strong believe that DACs are rotationally modulated.

Over the past decades, however, the exact origin and cause of DACs has remained elusive. The current thought is that DACs are due to either non-radial pulsations or stellar spots (or perhaps a combination of both). In this contribution we consider novel 3-D radiation-hydrodynamic models of rotating hot star winds and study the emergence of DACs due to stellar spots. In particular, we consider the effect of spot brightness, spot size, and spot latitude by modifying the flux distribution of the star. Additionally, we comment on first attempts to associate the stellar spot with a locally emerging small-scale surface magnetic field. Such small-scale surface magnetic fields are believed to originate from a dynamo operating in the spatially small iron-opacity recombination zone just below the radiative outer envelope of the star. Finally, we analyse the DACs in synthetic UV spectra created from a 3-D short-characteristics radiative transfer code.

KEYWORDS

IAUS 370

#1905

Stellar wind from low-mass main-sequence stars: an overview of theoretical models

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Stellar wind has a significant impact on the evolution of the stellar system. In terms of stellar evolution, the stellar wind is the principal source of the stellar angular-momentum loss in the main sequence, thus controlling the stellar spin down over a few Gyr. For planets, the stellar wind affects the loss of the atmosphere, both in positive and negative ways. Because of its observational difficulty, to prescribe the stellar wind from a given star, we often need a prediction from the model, which significantly depends on the theoretical and empirical assumptions used. Based on this background, I will review the current status of the stellar-wind modelings, focusing on the low-mass main-sequence stars. Beginning with some lessons from the solar wind observations, the driving mechanisms of the stellar wind are summarized in terms of energy and force balance. For each category of the models, I summarize the model assumption and the conclusion drawn from it. Future perspectives as to how the variety of the models would be integrated will also be discussed.

KEYWORDS stellar wind, magnetic braking, exoplanet

IAUS 370
#1612

Hydrodynamic disk solutions for Be stars using HDUST

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Classical Be stars (CBes) are fast rotating main sequence B-type stars forming an equatorial gas rotating disk. Close to the star, the disk is geometrically thin and rotates in a quasi-Keplerian way. These disks are built from mass that is ejected from the equatorial stellar surface that acquires sufficient velocity and angular momentum to orbit the star, these kind of disks are referred to as ”decretion” disks. It is a quite well established fact that CBes disks are driven by viscosity, and not radiation pressure. Viscosity acts to shuffle the angular momentum of the circumstellar material and the gas motion is assumed as Keplerian, then a steady and thermally-stable structure is obtained. However, recent results in the literature point to the fact that radiative forces act on top of viscosity to drive away disk material, a process known as disk ablation. In this work, we show preliminary results of using hydrodynamical solutions for the wind density of rapidly rotating massive stars, to be incorporated as input in the 3D Monte-Carlo radiative transfer code, HDUST, with the aim to build a disk model around CBes that include both the effects of viscosity and ablation.

KEYWORDS Physical Data and Processes: radiative transfer, line: profiles, stars: emission-line, Be

IAUS 370
#976

Signatures of star-planet interactions across the electromagnetic spectrum

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Close-in exoplanets can interact with their host stars magnetically, producing a variety of observable signatures at different wavelengths. For these interactions to occur, the planet must orbit inside the Alfvén surface of the stellar wind plasma, the region where magnetic forces dominate. As it is not generally possible to measure the plasma properties of the stellar winds of low-mass stars, the location of the Alfvén surface cannot be determined from observations. However, by coupling both observationally-derived magnetic field maps of the stellar surface and constraints on the stellar wind mass-loss rate with sophisticated magnetohydrodynamic models, we can obtain a 3D picture of the stellar wind plasma. This allows us to determine both the size and shape of the Alfvén surface, which in turn can be used to assess the feasibility of magnetic star-planet interactions occurring. In this talk, I will discuss how this approach allows us to predict and interpret hints of star-planet interactions at both radio and optical wavelengths. I will illustrate how obtaining near-simultaneous observations at these wavelengths is our best bet for benchmarking these magnetohydrodynamic models.

KEYWORDS star-planet interactions, stellar winds, exoplanets, radio emission

IAUS 370
#1606

Uncovering the Wolf-Rayet wind launching mechanism trough 3D radiation-hydrodynamics

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Mass loss mechanisms from massive stars in late stages of their evolution is still very much unknown. Stellar evolution models indicate that the last stage before going supernova for many massive stars is the Wolf-Rayet (WR) phase, characterized by a strong optically thick stellar wind.

Stellar models show that these stars exceed the Eddington limit already in deep sub-surface layers around the so-called 'iron-opacity' bump, and so should launch a supersonic outflow from there. Then, further out in the wind, the gas is accelerated more by line driving. However, in previous (1D) spherically symmetric models, the outer wind typically needed an artificial increase in either clumping or line force to prevent the wind from stagnating and falling back onto the stellar core due to a lack of driving force.

Here, we will present pioneering 3D time-dependent radiation-hydrodynamic simulations of WR winds which have no need for such an artificial increase. Our new multi-D models uncover how the launching mechanism of these winds relies on an interplay between structure formation around the iron bump, line drive acceleration of low-density regions in between the denser clumps, and momentum transfer from inter-clump medium to clumps via ram pressure.

KEYWORDS Wolf-Rayet, Winds, Outflows, Clumping, Hydrodynamics, Radiation force

IAUS 370

#1719

Advanced models of the solar wind, inner corona and heliosphere

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We perform 3D MHD simulations of the solar wind and inner corona and heliosphere for various recent dates. We confront their results to Solar Orbiter and Parker Solar Probe data, both using in situ and remote sensing observations.Using realistic data driven boundary conditions for the solar magnetic field, we compute the thermal, velocity and magnetic states of the solar wind and inner corona. We find a relatively good quantitative agreement when we include an Alfven wave and realistic heat transfer treatment. In quiet phases (2018-2019) this is enough to reproduce coronal holes and emissivity maps. In particular, EUV and X-ray real vs synthetic images comparison are useful tools to calibrate the models. In-situ properties are also globally well reproduced. When active regions are present in more recent periods (2021-2022), a better treatment of the chromosphere is needed to reproduce these bright regions in EUV as well as other large scale features in the solar corona and wind.

KEYWORDS corona, heliosphere, sun, solar orbiter, psp

The driving of hot star winds

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In the regime of hot stars, winds were not seen as a common thing until the era of UV astronomy. Since we have access to the UV wavelength range, it has become clear that winds are not an exotic phenomenon limited to some special objects, but actually ubiquitous among hot and massive stars. The fact that for most hot stars, the imprint of stellar winds is clearly visible only in their UV spectra, gives us the major hint that their acceleration mechanism is fundamentally tied to spectral lines in a certain wavelength range.

Indeed, the opacities due to spectral lines are the decisive ingredient that allows hot, massive stars to launch powerful winds. While the fundamental principles of these so-called line-driven winds have been realized decades ago, their proper quantitative prediction is still a major challenge today. Established theoretical and empirical descriptions have allowed us to make major progress on all astrophysical scales. However, we are now reaching their limitations as we still lack various fundamental insights on the nature of hot star winds, thereby hampering us from drawing deeper conclusions, not least when dealing with stellar or sub-stellar companions. This has spawned a new generation of researchers searching for answers with a yet unprecedented level of detail in observational and new theoretical approaches.

In this talk, I will review the fundamental principles of driving hot star winds. Starting from the classical CAK theory and its extensions, over Monte Carlo and recent comoving-frame-based simulations, I will introduce the different methods to describe and model the acceleration of hot star winds. After discussing first qualitative and quantitative insights gained with new approaches to understand OB- and Wolf-Rayet-star winds, I will outline the challenge of companions and how different types of them affect the driving and perception of hot star winds.

KEYWORDS hot stars, winds, line driving, massive stars, Wolf-Rayet stars, outflows, companions

IAUS 370
#872

Role of Longitudinal Waves in Alfven-wave-driven Solar/Stellar Wind

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We revisit the role of longitudinal waves in driving the solar wind. We study how the the p-mode-like vertical oscillation on the photosphere affects the properties of solar winds under the framework of Alfven-wave-driven winds. We perform a series of one-dimensional magnetohydrodynamical numerical simulations from the photosphere to beyond several tens of solar radii.

We find that the mass-loss rate drastically increases with the longitudinal wave amplitude at the photosphere up to ~ 4 times, in contrast to the classical understanding that the acoustic wave hardly affects the energetics of the solar wind. The addition of the longitudinal fluctuation induces the longitudinal-to-transverse wave mode conversion in the chromosphere, which results in the enhanced Alfvenic Poynting flux in the corona. Consequently, the coronal heating is promoted to give higher coronal density by the chromospheric evaporation, leading to the increased mass-loss rate.

This study clearly shows the importance of the longnitudinal oscillation in the photosphere and the mode conversion in the chromosphere in determining the basic properties of the wind from solar-like stars

KEYWORDS Stellar wind, Stellar wind, Corona, MHD, Alfven waves, Acoustic waves, Turbulence

IAUS 370
#2615

Filling the gap in stellar wind observations of cool stars via 3D MHD numerical modelling

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Stars interact with their planets through gravitation, radiation, and magnetic fields. Although magnetic activity decreases with time, reducing associated high-energy phenomena, stellar winds persist throughout the entire evolution of the system. Their cumulative effect will be dominant for both the star and for possible orbiting exoplanets, affecting in this way the expected habitability conditions. However, observations of stellar winds in low-mass main sequence stars are limited, which motivates the usage of models as a pathway to explore how these winds look like and how they behave. In this context, I will present the results from a grid of 3D state-of-the-art stellar wind models of cool stars (spectral types F to M). We explore the role played by the different stellar properties (mass, radius, rotation, magnetic field) on the characteristics of the resulting magnetized winds (mass and angular momentum losses, terminal speeds, wind topology) and isolate the most important dependencies between the parameters involved. These results are used to establish scaling laws that will complement the lack of stellar wind observational constraints.

KEYWORDS Space Weather, Star-Planet interaction, Stellar winds, Cool stars, Magnetic field, Exoplanets, Habitable zone

IAUS 370

#1647

ISOSCELES: Grid of stellar atmosphere and hydrodynamic models of massive stars. The first results

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Spectroscopy can decode the radiation from stars in an appropriate way and derive many properties of these objects. In this work we seek to derive simultaneously the stellar and wind parameters of massive stars, mainly A and B type supergiant stars. Our stellar properties encompass the effective temperature, the surface gravity, the micro-turbulence velocity, the rotational velocity and, finally, the chemical composition. For wind properties we consider the mass-loss rate, the terminal velocity and the line--force parameters (α, k and δ) obtained from the standard line-driven wind theory. To model the data we use the radiative transport code Fastwind considering the hydrodynamic solutions derived with the stationary code Hydwind. Then, ISOSCELES, a grid of stellar atmosphere and hydrodynamic models of massive stars is created. Together with the observed spectra and a semi-automatic tool the physical properties from these stars are determined through spectral line fittings. This quantitative spectroscopic analysis provide an estimation about the line--force parameters, whose theoretical calculations are complex. In addition, we confirm that the hydrodynamic solutions obtained with a value of δ slightly larger than ~0.25, called δ-slow solutions, describe quite reliable the radiation line-driven winds of B supergiant stars.

KEYWORDS hydrodynamics, methods: data analysis, stars: atmospheres, stars: winds, parameters, stars: early-type

IAUS 370

#414

Simulating the Space Weather in the AU Mic System: Stellar Winds and Extreme Coronal Mass Ejections

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Two close-in planets have been recently found around the M-dwarf flare star AU Microscopii (AU Mic). These Neptune-sized planets (AU Mic b and c) seem to be located very close to the so-called "evaporation valley" in the exoplanet population, making this system an important target for studying atmospheric loss on exoplanets. This process, while mainly driven by the high-energy stellar radiation, will be strongly mediated by the space environment surrounding the planets. Here we present an investigation on this last area, performing 3D numerical modeling of the quiescent stellar wind from AU Mic, as well as time-dependent simulations describing the evolution of a highly energetic Coronal Mass Ejection (CME) event in this system. Observational constraints on the stellar magnetic field and properties of the eruption are incorporated in our models. We carry out qualitative and quantitative characterizations of the stellar wind, the emerging CMEs, as well as the expected steady and transient conditions along the orbit of both exoplanets. Our results predict an extreme space weather for AU Mic and its planets. This includes sub-Alfvénic regions for the large majority of the exoplanet orbits, very high dynamic and magnetic pressure values in quiescence (varying within 102 - 105 times the dynamic pressure experienced by the Earth), and an even harsher environment during the passage of any escaping CME associated with the frequent flaring observed in AU Mic. These space weather conditions alone pose an immense challenge for the survival of the exoplanetary atmospheres (if any) in this system.

KEYWORDS Stellar Activity, Stellar CMEs, Stellar Winds, MHD Simulations, Exo-Space Weather

IAUS 370
#1335

Interaction between massive star winds and the interstellar medium

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Massive stars drive strong winds that impact on the surrounding interstellar medium (ISM), producing parsec-scale bubbles for isolated stars and much larger bubbles from the combined effects of many stars in young clusters. Stellar-wind bubbles such as the Rosette Nebula can be observed across the electromagnetic spectrum, both the wind itself and the swept up interstellar gas. Wind bubbles are often most prominent, however, for the runaway massive stars, where the supersonic motion of the star drives a bow shock that strongly compresses interstellar gas, producing bright infrared (and sometimes optical and radio) nebulae. The evolved Wolf-Rayet stars with strong winds that drive supersonically expanding bubbles, produce prominent nebulae, also in X-rays. The kinetic energy of stellar winds, transformed to thermal energy at the wind termination shock, appears to be efficiently dissipated by radiation from mixed gas at the wind-ISM boundary. Quantifying this effect is important for assessing stellar-wind feedback in the context of our understanding of the dynamic ISM of galaxies. It is also relevant for chemical enrichment of the ISM by winds from evolved stars. I will review recent progress on theory and observations of nebulae produced by stellar winds from both hot and cool massive stars, isolated and in star clusters. X-ray observations of diffuse emission from star clusters, wind bubbles and bow shocks with Chandra and XMM-Newton provide strong constraints on the bubble energetics and the wind-ISM interface. Together with multi-dimensional gasdynamics simulations, now in 3D and including magnetic fields, it is becoming possible to make quantitative comparisons between theory and observations and to test the importance of some physical processes such as thermal conduction and gas-grain coupling. With the detection of non-thermal radio emission from bow shocks and Wolf-Rayet nebulae, it is also becoming possible to investigate particle acceleration in stellar-wind shocks, and this is a key area for future advances with next-generation observatories where detection of non-thermal X-rays and gamma-rays are expected in some cases.

KEYWORDS Massive stars, stellar winds, magnetohydrodynamics, particle accleration, X-ray astronomy, stellar evolution, circumstellar nebulae

IAUS 370
#686

Stellar winds and the survival of planets

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Winds play a fundamental role in the survival of planets once the star leaves the main sequence. The orbital evolution of the planet depends strongly on the stellar mass-loss but also on the stellar and planet mass via tidal interaction. Moreover, winds have an effect in determining orbital decay rates via drag forces as they increase the density of the environment. Stellar winds can trigger as well dynamical instabilities and cause that multiple planet systems stable on the main sequence become unstable later on in the evolution of the star. We have explored all this phenomena together in order to determine the probability of planet survival and to provide predictions on the location of planets once the star reaches the white dwarf phase. In this talk I will summarize the role that stellar winds have in the orbital evolution of planets during the different stages of the star: red giant, asymptotic giant phase and white dwarf.

KEYWORDS winds, orbital evolution, planets, dynamical evolution and stability, AGB and post-AGB, white dwarfs

IAUS 370
#342

Interaction of exoplanetary and stellar winds and its observational manifestations

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Among very diverse planetary populations, close orbiting hot exoplanets possess a unique feature of hydrodynamic outflow of upper atmospheres. This phenomenon was revealed for a number of hot Jupiters and warm Neptunes via observations of transit absorption in VUV lines of such elements as H, He, C, O, Mg, Si. The multicomponent and partially ionized atmospheric material overflowing with a supersonic velocity the Roche lobe collides with the stellar wind plasma. This interaction principally differs from the processes in tenuous planetary exospheres in the Solar system. The escape of upper atmospheres of hot exoplanets is a complex phenomenon, and quantitative interpretation of observational data requires numerical simulations. The comparison of spectrally resolved transit measurements of particular exoplanets and 3D simulations of their dynamical environments gives a tantalizing evidence of planetary and stellar winds interaction, enabling to draw important conclusions about both the atmosphere of an exoplanet and the parameters of the stellar wind plasma. In this review, we summarize about two decades of a rapid development of the modelling approaches from relatively simple semi-empirical formulas to the large-scale 3D multi-fluid aeronomic models and global Monte-Carlo and MHD codes. Fast increase of quality and amount of observations, new instruments, new approaches to the probing of planetary winds, including the new spectral windows, multi-spectral and multi-instrumental observations of targets require further development of the modeling tools capable of complex simulation and interpretation of all available observations.

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KEYWORDS planetary wind, stellar wind, exoplanets

IAUS 370

#748

Massive star mass loss constrained by supernova radio properties

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Supernova (SN) properties in radio strongly depend on their circumstellar environment and they are an important probe to investigate mass loss of SN progenitors. Recently, core-collapse SN radio observations have been assembled and the rise time and peak luminosity distribution of core-collapse SNe in radio has been obtained. In this talk, I will discuss mass-loss prescriptions of massive stars constrained by the assembled radio SN properties. We first discuss the mass-loss prescriptions for red supergiants (RSGs) obtained from Type II SNe in radio. We take the de Jager and van Loon mass-loss rates for RSGs, calculate the rise time and peak luminosity distribution based on them, and compare the results with the observed distribution. We found that the de Jager mass-loss rate explains the widely spread radio rise time and peak luminosity distribution of Type II SNe well, while the van Loon mass-loss rate predicts a relatively narrow range in the rise time and peak luminosity. We conclude that the mass-loss prescriptions of RSGs should have strong dependence on the luminosity as in the de Jager mass-loss rate to reproduce the widely spread distribution of the rise time and peak luminosity in radio observed in Type II SNe. Similarly, the radio properties of Type Ibc SNe indicate that Wolf-Rayet SN progenitors generally have mass-loss rates higher than ~ 1e-6 Msun/yr. Such a high mass-loss rate is not expected in some Wolf-Rayet mass-loss prescriptions, but it is possible that Wolf-Rayet SN progenitors generally experience mass-loss enhancement shortly before their explosion.

KEYWORDS supernovae, massive star, mass loss, radio

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#387

Time-dependent Numerical Modeling of Thermally Driven Stellar Winds

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Kinetic and thermal feedback from a cluster of massive OB stars in H II regions can result in the formation of stellar winds and bubbles on a large scale. The non-equilibrium evolution of stellar winds thermally driven by massive stars and their radiative feedback can be investigated through numerical hydrodynamic simulations. For this work, we conducted a series of adaptive mesh hydrodynamic simulations of fluid equations coupled to radiative cooling and photo-heating functions. Our time-dependent hydrodynamic results were then supplied as inputs to photoionization models in order to produce volume emissivities of UV and optical lines generated by collisional ionization, non-equilibrium ionization, and photoionization. Our predicted UV and optical lines will help identify better various superwind modes such as adiabatic, radiatively cooled, and pressure-confined winds driven by thermal pressures in star-forming regions.

KEYWORDS Stellar Winds, Massive Stars, Bubbles, Radiative Cooling, Non-equilibrium Ionization, Collisional Ionization, HII Region

IAUS 370

#373

Probing the winds and interactions of OB stars in different environments

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To understand the evolution and feedback of massive stars, it is important to empirically constrain the wind properties of massive stars in different environments. Using detailed atmosphere analyses of low metallicity OB stars, we provide their stellar and wind parameters including chemical abundances. By characterizing their winds, we empirically establish the scaling of mass-loss with metallicity. Empirical measurement of winds of massive stars can be affected by the presence of a companion. For main sequence stars, we test this discrepancy by studying UV + optical spectra of O star binaries. To understand the role of metallicity, we investigate similar early O-type binaries in the SMC, LMC, and Galaxy. On the other hand, the presence of a compact companion can severely alter the wind properties of OB stars. I will briefly discuss the wind properties of O donors with black hole companions such as M33 X-7 and Cygnus X-1. Using a multi-wavelength (Xray+UV+optical) spectral analysis, we studied the wind structure of the O-star donor including the impact of X-ray photoionization. At the end of the talk, I will summarize recent spectroscopic studies of metal-poor OB stars and their role in creating superbubbles and shells in the Magellanic Clouds.

KEYWORDS massive stars, wind mass-loss, low metallicity, feedback, binaries, spectroscopy

IAUS 370
#287

Role of Planetary Winds in Planet Evolution and Population

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Atmospheric evaporation and its role in shaping exoplanet populations remains a major unsolved problem in the field. This review talk will cover the fundamental physics behind the role of X-ray and ultraviolet irradiation in shaping the histories and evolutions of exoplanets. Observational evidence, like the bimodal distribution of exoplanet radii, is suggestive of a catastrophic past in which exoplanets with masses of approximately 1-10M lost their primordial envelopes and experienced a drastic reduction in their radii. Further evidence comes from discovering exoplanets with densities higher than iron, with the most likely explanation for their formations being that they once possessed large primordial atmospheres that left their central embryos in a severely compressed state. Our understanding of the mechanism behind atmospheric evaporation remains nebulous, with new models constantly being introduced in the literature. Understanding the principles behind these models and knowing when to apply them is essential for constraining how planets evolve and effectively evaluating what systems are most favorable for the formation of life.

KEYWORDS Exoplanet, Super-Earth, Sub-Neptune, Photoevaporation, Atmospheres, XUV, Interiors

IAUS 370
#1470

Rotation of the Solar Corona and Solar Wind Angular Momentum-loss

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The rotational-state of the solar corona is challenging to decipher, and is nearly impossible to directly measure. Understanding coronal rotation is vital for multiple topics of ongoing research, ranging from studies of solar wind connectivity (to the various Heliospheric spacecraft), to studies of the rotation-evolution of Sun-like stars. Stars like the Sun efficiently shed angular momentum via magnetized stellar winds. These winds remove a relatively miniscule mass-flux, but the presence of a large-scale stellar magnetic field acts to exchanges angular momentum with the outflowing plasma out to large distances. With Parker Solar Probe (PSP) now sampling the solar wind at “sub-alfvenic” distances (less than 15Rsun), it has become clear that the rotation of the solar corona is more structured and dynamic that previously thought, with large tangential flows of up to 50km/s detected in the near-Sun environment. Differences between current magnetohydrodynamic models of the solar wind rotation, and that measured by PSP are likely linked to the transport of angular momentum from the photosphere into the low-corona and beyond. The rotational state of the “coronal base” is heavily debated, and will likely remain uncertain. However, with the wealth of new Heliospheric missions/observatories (PSP, Solar Orbiter, DKIST, Vigil,…), and existing infrastructure (SOHO, STEREO-A, SST,...), we may soon be able to constrain the rotation of the solar corona/wind, and subsequently apply this knowledge to the coronae of other Sun-like stars. This includes measuring more precisely the angular momentum-loss rate of the current Sun, in comparison to that predicted by models of rotation-evolution (for which the rotation period-evolution of Sun-like stars at, or older than, the age of the Sun, is current highly debated).

KEYWORDS Solar-Stellar Connection, Solar Wind, Angular Momentum-loss, Near-Sun Environment, Rotation-Evolution

IAUS 370
#1270

Size Evolution of Close-in Super-Earths through Giant Impacts and Photoevaporation

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The KEPLER transit survey with follow-up spectroscopic observations has discovered numerous super-Earth sized planets and revealed intriguing features of their sizes, orbital periods, and their relations between adjacent planets. The planet size distribution exhibits a bimodal distribution separated by a "radius gap" at around 1.8 Earth radii. Besides, super-Earths within multiplanet systems show that adjacent planets are similar in size and their period ratios of adjacent planet pairs are similar as well, a phenomenon often dubbed as “peas-in-a-pod” in the exoplanet community. While the "radius gap" has been predicted and theorized for years, whether it can be relevant to the orbital architecture "pears-in-a-pod" is physically unknown. For the first time, we attempt to model both features together through planet formation and evolution processes involving giant impacts and photoevaporation. we shall show that our model is generally consistent with the KEPLER results. The radius gap would be reproduced if we perform simulations in which the initial radial profile of the core mass follows a wide range of power-law distributions and the initial envelope mass fractions are ~0.1.

KEYWORDS exoplanet atmospheres, exoplanet formation, exoplanet evolutions, exoplanet dynamics

IAUS 370

#2556

Effects of rotation on the evolution of early-type stars

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A large fraction of early-type stars are observed as rapid rotators and rotation is supposed to play a key role in their evolution by inducing chemical mixing and significantly affecting the mass-loss history. To make stellar evolution models of rotating stars, we have to consider various uncertain physical processes: angular momentum redistribution, chemical mixing induced by rotational instabilities, mass loss enhancement/mass shedding due to rotation, etc. These effects may become even more important for close binary systems where angular momentum exchange due to mass transfer and tidal interactions would occur. In this talk, I will first discuss the theoretical efforts for incorporating these processes in stellar evolution models. Then I will present a few examples of how these effects of rotation can change the course of massive star evolution. I will conclude the talk by discussing how to test theoretical predictions observationally.

KEYWORDS massive stars, rotation, mass loss, stellar evolution

IAUS 370

#2472

The Evolution of Atmospheric Escape of Highly Irradiated Gassy Exoplanets

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Atmospheric escape has traditionally been observed in Lyman-alpha transits, but more recently detections using the metastable helium triplet 1083nm line were obtained. Given its ability to be observed from the ground, the 1083nm helium line offers more possibilities for studying atmospheric escape. One issue however is that the formation of this line is strongly dependent on the specific high-energy flux received by the planet. Previous studies have shown that the extreme-UV band both drives atmospheric escape and populates the triplet state, whereas lower energy mid-UV radiation depopulates the triplet state through photoionisations. This is supported by the current detections, in which the majority of planets with Helium escaping atmospheres orbit a K-type stellar host, which emits a favourably high ratio of EUV to mid-UV flux. The goal of our work is to understand how the observability of escaping helium evolves as the planet ages. For that, we couple our one-dimensional hydrodynamic non-isothermal model of atmospheric escape with a ray tracing technique in order to predict the physical nature and observability of escaping helium as the planet ages. In our models, we consider the evolution of the stellar high-energy radiation and the evolution of the planet gravitational potential, both of which contribute to a decline in the rate of atmospheric escape. We show that the time at which atmospheric escape is strongest may not necessarily correspond to when the escape is most observable in the helium line.

KEYWORDS Exoplanets, Atmospheres, Atmospheric Escape, Hydrodynamics, Planetary Evolution, Gaseous planets

IAUS 370

#257

Spin down and reduced mass loss in early-type stars with large-scale magnetic fields

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Stellar evolution theory has progressed over the decades by incorporating key physical modelling ingredients such as rotation and mass loss. Thus far, the impact of large-scale fossil magnetic fields has seldom been considered in stellar structure and evolutionary models with > 3Msun. To bridge this gap, we have developed a new grid of early-type stars consisting of 24000 structure and 8000 evolutionary models of stars with fossil fields. I will present the key physical characteristics of this grid. I will show how a depth-dependent application of magnetic braking can deplete the stellar angular momentum reservoir. Large-scale dipolar fields lead to solid-body rotation, which results in slowly spinning stellar cores. More complex magnetic fields may allow for differential rotation in the deep stellar layers and consequently, leave the core angular momentum intact while spinning down the stellar surface. I will demonstrate that independent of the metallicity, stellar winds can be reduced by over an order of magnitude accounting for dipolar and quadrupolar field geometries. The mass-loss quenching mechanism by large-scale magnetic fields also has implications towards stellar end products. The magnetospheric evolution of the star can be quantified and compared with observable diagnostics (e.g., Halpha variability). Understanding the rotational-wind-magnetic evolution of early-type stars thus has the potential to develop new chronology methods and gain more detailed insights into the past, present, and future of stars.

KEYWORDS early-type stars, magnetic fields, mass loss, stellar rotation, stellar evolution, massive stars, fossil fields

IAUS 370
#1423

Architectures of rotating star-planet systems: Comparing theoretical predictions to observations

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Over the last two decades, a large population of close-in planets has been detected around a wide variety of host stars. But where does this population originate from? Such exoplanets are likely to undergo planetary migration during the whole evolution of the star-planet system, from their formation in a disk to the end of the main sequence. The late migration occurs through magnetic and tidal interactions. We aim to characterize systematically star-planet interactions and to investigate their influence on the secular evolution of exosystems.

We have developed a numerical model of a coplanar circular star-planet system taking into account stellar structural changes, wind braking and star-planet interactions, called ESPEM (Benbakoura et al. 2019). The evolution of stellar properties (rotation, magnetism) is followed by an original approach relying on the combination of grids of stellar evolution and power-law prescriptions compatible with gyrochronology and observations of stellar magnetic fields through spectro-polarimetry. We browse the parameter space of star-planet system's configurations and assess the relative influence of magnetic and tidal torques on the secular evolution of a star-planet system (Ahuir et al. 2021). We then present synthetic star-planet populations and show that the distribution of the Kepler-field in orbital and stellar rotation periods (McQuillan et al. 2013, Santos et al. 2021) can be recovered using realistic populations during the disk-phase and tidal and magnetic migration in the post-disk phase. More precisely, we find that star-planet magnetic interactions significantly affect the distribution of super-Earths around slowly rotating stars, while tidal effects are found to shape the distribution of giant planets. We finally discuss the implications of the post-disk migration on the stellar spin-down when planets are engulfed by their host star.

KEYWORDS planet-star interactions, architecture of exosystems, stars: evolution, stars: evolution, stars: evolution

IAUS 370
#1480

Mass-loss implementation and temperature evolution of very massive stars

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The extreme winds of Very massive stars (VMS) not only dominate the evolution of such objects by continuously losing mass throughout their lifetime, but also influence the physics of the surrounding medium due to their strong ionising and mechanical feedback. Already during the main-sequence (MS) that spans nearly 90% of the entire lifetime, VMS can lose a large fraction of their initial mass due to their extremely high luminosities. Despite the MS mass loss shaping the evolution of these objects and their final fates, we know very little regarding the properties of the winds in close proximity to the Eddington limit. Using the 1D stellar evolution code MESA we focus on the MS evolution of VMS with a new theoretically informed mass-loss recipe that naturally switches from a canonical optically-thin O-star wind to an enhanced optically-thick Wolf-Rayet (WR) type wind above a certain model-independent transition mass loss point. We find our VMS models to steeply drop in luminosity and evolve almost vertically in the Hertzsprung-Russel (HR) diagram at nearly constant Teff, which naturally explains the narrow range of VMS temperatures observed in both the Arches Cluster near the Galactic center and the 30 Dor region in the LMC. This distinct behavior of a steeply dropping luminosity is shown to have a self-regulatory effect that keeps temperatures constant during evolution in the HR-diagram. We also show that VMS with an initial mass greater than 200 Msun undergo chemically homogeneous evolution throughout the MS. Mass loss becomes the single-most important process deciding the fate of these stars, and even tiny uncertainties in the input mass loss can result in vastly different evolution. Future hydro-dynamical mass-loss predictions from state-of-the-art model atmosphere codes can perhaps shed light on the wind properties of these highest mass stars.

KEYWORDS Winds, Evolution, Mass loss, VMS

IAUS 370

#3410

Effect of stellar magnetic fields on the evaporative winds of exoplanets

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The Lyman-α profile of extra-solar hot Jupiters and hot Neptunes can be observed in great detail by telescope spectrographs. The profile can be explained by escaping hot, neutral Hydrogen from the planets at speeds of approximately ~100 km/s and ~150 km/s for the blue-shifted and red-shifted wings respectively. In our previous simulations on this subject using the adaptive mesh refinement multiphysics code AstroBEAR, with sufficiently high stellar wind ram pressure along with modest ionizing fluxes, we were able to obtain speeds >50 km/s before all the neutral H was ionized. Stellar wind ram pressure (as opposed to Lyman-α radiation pressure) remains the best candidate for explaining the blue wing but cannot explain the red wing. Charge exchange can create absorption in both the red and blue wings - but it remains unclear whether this mechanism is sufficient to explain the current observations. In this ongoing project, we investigate the ability of stellar magnetic fields to convert orbital wind ram pressure into radial motions both towards and away from the star on time scales small enough to avoid the ionization of the escaping neutrals.

KEYWORDS magnetohydrodynamics, planets and satellites: atmospheres, planet-star-interactions

IAUS 370

#3365

Atmospheric escape in magnetised hot Jupiters: double tail structures

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High-energy stellar irradiation can photoevaporate planetary atmospheres, which can be observed in spectroscopic transits of hydrogen lines. Here, we investigate the effect of planetary magnetic fields on the observational signatures of atmospheric escape in hot Jupiters. For that, we use 3D radiative MHD simulations and Lyman-α transit calculations. Using the same stellar wind, we vary the planet's dipole field strength from 0 to 10G. We demonstrate that atmospheric escape in magnetised planets (> 3G) occurs through polar outflows, as opposed to the predominantly comet-like tail from non-magnetised models. The polar outflows seen in magnetised planets lead to the formation of a double tail structure, above and below the orbital plane, and a dead-zone around the equator. This structure has some key effects in Lyman-α transit signatures: 1) As the size of the dead-zone increases with field strength, so does the line centre absorption in Lyman-α, as more low-velocity neutral hydrogen covers the stellar disc during transit. 2) The blue wing absorption initially decreases upon the introduction of the planetary field, as planetary material begins to be launched above and below the orbital plane, instead of being fully funnelled on to the orbital plane by the stellar wind, as seen in the 0G model. As the field strength continues to increase we see the blue wing absorption also increases. 3) The red wing absorption increases with planetar magnetic field strength. Most of the red shifted material exists around the night-side orbital plane, as some material falls from the comet-like tails back towards the planet. Finally, we find a small increase in escape rate with planetary field, though this should not affect the timescale of atmospheric loss.

KEYWORDS exoplanets, magnetic fields, radiation MHD, atmospheric escape

CO Outflow Survey of Very Low Luminosity Objects using TRAO 14m telescope

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We present the results of our new CO survey of Very Low Luminosity Objects (VeLLOs). The observing targets for the VeLLOs were newly selected from the Herschel Science Archive catalog of the faint point sources having their internal luminosity less than 0.1 $L_{\odot}$ and protostellar SEDs (i.e., Tbol < 650 K). This resulted in the construction of a catalog of 438 new VeLLOs which were not previously known. We used TRAO-14m telescope (angular resolution of ~53" at 115 GHz) to make a survey of outflow activity in the number of 253 VeLLOs in CO and 13CO J=1-0 lines in OTF mode which are observable in the northern sky. A total of 117 VeLLOs were observed around 5 x 5 arcmin2 area for each source in a rms of 0.3 K and the velocity resolution of 0.12 km/s. So far 6 sources are found to show a strong hint of outflow activity in a bipolar shape or one sided outflow. There are 20 of VeLLOs also showing wide wing features toward the sources.

Detailed analysis is ongoing to derive the physical properties of these outflow candidates such as their mass accretion rates and accrete masses which will be highly useful to discuss their possible identification such as proto-brown dwarfs or very young protostellar objects and the implication on the formation of stellar or substellar objects.

KEYWORDS VeLLO, Star Formation, Outflow, Brown Dwarf

IAUS 370

#3235

Chemical Characterization of Planet Hosting Solar Twins

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We present preliminary results of general properties of planet hosting solar-type stars (PHSs). We used the data from APOGEE and Gaia data release 3 to select solar twins stars in the Galactic disk, and cross-matched them with confirmed exoplanet catalog of Nasa Exoplanet Archive in order to identify the PHSs. By this process, we obtained the general properties of their planets, which provide chemical abundances of 37 solar twins, which host 57 exoplanets. First, we investigate discrepancies in chemical abundance ratios between the PHSs and non-planet hosting stars (NHSs). And then we attempt to derive the condensation temperature for each element after we estimate ages of our samples with Yonsei-Yale isochrones and correct the Galactic chemical evolution effects. From the study of the impact of planets on their host star's atmospheric abundances, we find that the depletion of refractory elements in the solar twins are potentially correlated with the existence of planets, particularly the terrestrial planets. As noted in previous studies, we also confirm that the trends of elemental abundance differences between PHSs and NHSs as a function of condensation temperature depend on the planetary multiplicity.

KEYWORDS planetary systems, stars: solar-type, stars: atmospheres, stars: abundances, stars: kinematics and dynamics, Galaxy: evolution, Galaxy: disk

IAUS 370
#3192

Signatures of wind formation in optical spectra of precursors of planetary nebulae

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The role of different processes in shaping of planetary nebula (PN) around post-AGB stars is not fully understood. Recently, binary interactions have been thought of as the main shapers of PN; however, cases that seem to defy this idea are known. It is possible that an intrinsic change in the nature of stellar wind of a single star during the post-AGB phase plays an important role in the formation of the PN. Our recent studies of the bright post-AGB stars HD 235858 and HD 161796 have revealed seemingly wind-related processes in their atmospheres. Shocks and both cool and warm outflows have been observed. Also, other dynamic processes such as matter falling onto the star have been detected. Our results suggest that high-resolution spectroscopic monitoring of post-AGB objects is a useful tool for study of dynamical phenomena in their atmospheres and surrounding shells and has a potential to improve the knowledge about mass loss processes in such stars.

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KEYWORDS

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#2996

Magnetic interaction between the exoplanet and its host star based on LAMOST, TESS and FAST telescopes

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The magnetic activity of the host star of exoplanets and the magnetic field interaction between stars and planets will affect the habitability of exoplanets. With the increase of the number of exoplanets, the research on the law and mechanism of magnetic activity of its host star has become a very meaningful thing. Based on the low and medium resolution spectral data of the Large Sky Area Multi-Object Fiber Spectroscopic Telescope (LAMOST), we studied the activity of exoplanet host stars through Hα and CaIIH&K lines.

At the same time, we used the light curves of Transiting Exoplanet Survey Satellite (TESS) and Kepler telescopes to detect the flare events. We searched 2834 flares from 563 stars. The maximum energy of M, K and G dwarfs are 1.66× 1034 erg, 2.94 × 1035 erg and 4.74 × 1035 erg respectively. The power-law index of the flare frequency distribution of different spectral data at different exposure times of the two telescopes is between 1.66-2.26. By comparing the power-law index of the flare frequency distribution of each spectral type, it is found that stars with different spectral types have similar power-low index. In addition, we also judged the habitability of exoplanets from the energy scale of flares combined with the semi-major axis of exoplanet orbit. We have discovered 21 exoplanets that are habitable at the flare scale in star systems with flares.

Finally, we estimated the intensity of radio radiation generated by the magnetic activity between exoplanets and their host stars. The sensitivity of FAST telescope is fully capable of observing the interaction between them. We will use fast telescope to study the interaction process of magnetic field between the host stars and exoplanets.

KEYWORDS exoplanets, activity-stars, flare-stars, chromospheres-stars, magnetic activity, planetary radio, host star

Collision between the stellar wind and the accretion disk in Be/X-ray binaries

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About a half of high-mass X-ray binaries have Be stars as the mass donor. Here, a Be star is a non-supergiant OB star with a circumstellar disk formed by viscous diffusion of gas ejected from the equatorial region of the central star. Since these Be/X-ray binaries have, in general, eccentric orbits, the compact object, mostly a neutron star, can capture gas from the Be-star's circumstellar disk only for a short period of time around periastron. This explains why most Be/X-ray binaries are transient X-ray sources.

Previous studies of the X-ray activity in Be/X-ray binaries have focused on the accretion due to the tidal interaction between the neutron star and the circumstellar disk. Indeed, the estimated accretion rate of the stellar wind in these systems is much smaller than that via the circumstellar disk. It is, however, an open question whether the stellar wind significantly affects the accretion rate by modifying the accretion flow structure via its large ram pressure.

In this paper, I will discuss the effects of the stellar wind on accretion in Be/X-ray binaries, on the basis of the result from 3D SPH simulations of the collision between the stellar wind and the accretion disk in these systems.

KEYWORDS X-ray binaries, stellar wind, accretion, hydrodynamics

IAUS 370
#1648

Hydrodynamic solutions of radiation driven wind from hot stars

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We summarize the known three different solutions from the CAK theory of radiation driven wind from hot stars. We show that different current "problems" can be solved applying these different types of solutions, e.g., weak winds, winds from late B supergiants and disks around Be stars. Special focus will be given to the \Omega-slow solution at the equatorial plane of fast rotating objects.

This \Omega-slow solution, shows a slow outflowing decretion disk with a density about 10-1000 times larger than the wind present in medium and polar latitudes. Time dependent calculations shows that a perturbation at the base of the wind can trigger a switching of solutions, where the decretion disc can be created or dissipated.

The terminal velocities reached by the \Omega-slow solution is larger than the observed values, and to solve this theoretical problem, we discuss two models that include viscosity effects on these decretion outflowing disk. With these radiation-driven plus viscosity models we can explain the truncated disk observed in Be stars without needing a binary companion.

Finally, we lucubrate about the possible link of these decretion disks and exoplanet formation.

KEYWORDS stellar winds, early type stars, mass loss, hydrodynamics, circumstellar discs, rapid rotation

IAUS 370

#1630

Variable and Supersonic Winds in the Atmosphere of an Ultrahot Giant Planet

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Hot Jupiters (HJs) present an extreme case for exploring the conditions that regulate planetary atmospheres because they experience intense irradiation from their host stars that induce global-scale winds. General circulation models (GCMs) of HJ atmospheres predict day-to-nightside winds (winds flowing from the side of the planet facing its host star to the side facing away from the star) and equatorial jets (winds that entirely circulate around the planet) with speeds on the order of a few km/s. We apply high-resolution transmission spectroscopy using the PEPSI spectrograph on the Large Binocular Telescope to empirically constrain supersonic ~10 km/s day-to-nightside winds traced by Fe II features in the atmosphere of KELT-9 b, an ultra-hot Jupiter (UHJ) that remains to-date the hottest known planet. Reconciling our findings with archival HARPS-N datasets suggests multi-epoch variability ~5-8 km/s over timescales between weeks to years. We compare with the UHJ KELT-20 b to demonstrate the exceptional nature of KELT-9 b's atmospheric dynamics. A qualitative evaluation of our measured wind velocities and variability against current UHJ GCMs reveals that KELT-9 b poses unique challenges for validating giant planet atmospheric models.

KEYWORDS exoplanet atmospheres, atmospheric variability

IAUS 370
#1510

Spectral signature of atmospheric winds in high resolution transit observations

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The study of exoplanet atmospheres showed large diversity compared to the planets in our solar system. Especially Jupiter-type exoplanets orbiting their host star in close orbits, the so-called hot and ultra-hot Jupiters, have been studied in detail due to their enhanced atmospheric signature. Due to their tidally locked status, the temperature difference between the day- and night sides triggers atmospheric winds which can lead to various fingerprints in the observations. Spatially resolved absorption lines during transit such as sodium (Na) could be a good tracer for such winds. Different works resolved the Na- absorption lines on different exoplanets which show different line widths. Assuming that this could be attributed to such zonal jet streams, this work shows the effect of such winds on synthetic absorption lines. For this, transiting Jupiter-type planets with rotational velocities similar to hot and ultra-hot Jupiter are considered. The investigation shows that high wind velocities could reproduce the broadening of Na-line profiles inferred in different high-resolution transit observations. There is a tendency that the broadening values decrease for planets with higher equilibrium temperature. This could be explained by atmospheric drag induced by the ionization of alkali lines which slow down the zonal jet streams or by the decrease of the effective radiative timescale for hotter planets, favoring high wind velocities on hot Jupiter rather than ultra-hot Jupiter type planets.

KEYWORDS High resolution, Hot Jupiter, Winds, Transmission spectroscopy

IAUS 370

#1504

Weakening the winds with the ULLYSES data set: examining the presence of a bi-stability jump

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Radiation-driven mass-loss is an important, but still highly debated, driver for the evolution of massive stars. Current massive star evolution models rely on the theoretical prediction that low luminosity massive stars experience a sudden increase in mass loss below a stellar effective temperature of about 20 000 K. This so-called bi-stability jump is thought to originate from the change in ionisation state of iron lines inside the wind. However, novel radiation-driven mass-loss rate predictions show no such bi-stability jump (Bjorklund et al. 2022). Instead, stellar mass loss decreases with decreasing stellar luminosity/temperature, which may potentially affect the post main-sequence evolution of massive stars differently than hitherto anticipated.

The ULLYSES data set provides a unique opportunity to investigate the theoretical bi-stability jump dichotomy and may help to assess the existence of the bi-stability jump in massive star winds. By utilising UV spectra from ULLYSES combined with X-shooter optical data it is possible to obtain empirical mass-loss rate constraints, that are no longer degenerate to the effects of wind clumping, and derive novel empirical constraints on the mass-loss behavior across the temperature range of the bi-stability jump.

In this talk, I will first present new line-driven theoretical models from Bjorkund et al. (2019, 2021,2022), which are developed in our research group at the KULeuven, and explain why these do not show any sign of a bi-stability-jump in mass loss. Additionally, I will show some first, tentative empirical results for stars around the bi-stability region, based on genetic algorithm fits of UV+optical ULLYSES data by means of the FASTWIND code. Empirical results will be compared to the new theoretical predictions, and the results will be discussed in the broader context of what the (potential absence of a) bi-stability jump means for massive-star evolution predictions.

KEYWORDS Stellar Winds, Mass Loss, Massive Stars, Bi-stability Jump, Stellar Atmospheres

IAUS 370
#1336

3D Magnetohydrodynamic models of prominent bow shocks

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Bow shocks from runaway massive stars are some of the most prominent nebulae in the mid-infrared sky. They are also relatively simple systems to model, and potentially much can be learned about (1) stellar-wind feedback to the ISM and (2) particle acceleration in fast shocks, from comparison of observations with simulations that include different physical processes. We will present 3D magnetohydrodynamic (MHD) simulations of the bow shock of the nearby O star, Zeta Ophiuchi, the runaway star BD+60 2522 driving the Bubble Nebula, and of the bow shock of BD+43 3654, a massive star ejected from the Cygnus region. Synthetic observations from the simulation results will be compared with observational data from radio to gamma-rays. The sensitivity of thermal X-ray emission to model parameters will be examined, and the relationship between non-thermal radio emission and optical line emission will be explored.

KEYWORDS massive stars, stellar winds, bow shocks, magnetohydrodynamics, particle accleration

IAUS 370
#972

Water and silicon-monoxide masers monitored towards the "water fountain" sources

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The "water fountain" sources (WFs) are classified as water (H2O) maser sources associated with a high velocity, collimated outflow or jet driven by a dying star in the transition of the asymptotic giant branch (AGB) to post-AGB phase. Recent ALMA observations suggest that they are likely experiencing the common envelope evolution of low to intermediate-mass binary stars with their highest mass loss rate (up to 10^-3 M_sun yr^-1) for a period shorter than 100 yr. If those parameter values are true, one can directly see the evolution of the WF in real time during our lifetime in the accompanying H2O and silicon-monoxide (SiO) masers. These masers are excellent probes of new blob ejections, acceleration and/or deceleration of the stellar jets and possible periodic behavior of the central dying stars or the binary system over decades.

Here we present the current status of our FLASHING (Finest Legacy Acquisitions of SiO-/H2O-maser Ignitions by Nobeyama Generation) project, which has been conducted using the Nobeyama 45-m radio telescope since 2018 December and followed by interferometric observations for the WFs. The intensive single-dish monitoring has enabled us to catch new spectral components exhibiting the jet speed breaking its previous record. It also has yielded an unpredictable detection of SiO masers implying the new evolutional transition at a higher stellar mass loss. Moreover it has found systematic drifts of the spectral profiles of the H2O masers suggests that the masers are associated with entrained material supplied from a parental circumstellar envelope (CSE) and accelerated by the fast jet. Interferometric observations show that the highest velocity components of H2O masers may trace blobs of jets which are drilling the parental CSE and contributing to further growth of the jet.

Our presentation summarizes how the masers have traced the evolution/devolution of the WFs even for a few decades and emphasizes the importance of synergetic monitoring campaigns for the WFs.

KEYWORDS AGB and post-AGB stars, masers, outflows

IAUS 370

#960

Detection of AlF line emission in the outflow around M-type AGB stars

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The cosmic origin of fluorine is still uncertain. AGB stars are among the few candidates to synthesis F in our Galaxy, however their contribution is not clear. In this talk, I will present first detection of AlF line emission, one of the two main carriers of F in the gas-phase in the outflow of AGB stars, towards a sample of five oxygen-rich AGB stars with ALMA. I will present the results of estimating the AlF column density and fractional abundance in our sample and compare it with the Solar F budget. I will show that the AlF fractional abundance which gives a lower limit to the total F budget in the gas phase in the CSE is consistent with the Solar F budget in all observed sources in our sample. Finally, I will discuss the ongoing work of observationally tracing the role of AGB stars in the total F budget in our galaxy.

KEYWORDS AGB stars, circumstellar matter, abundances, nucleosynthesis, AGB wind, Fluorine

IAUS 370

#953

Jupiter-like planets around Sun-like AGB stars could evolve to red-giant hot Jupiters

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Planets that orbit low- to intermediate stars will experience vigorous star-planet interactions when their host star evolves through the giant branches, including the Asymptotic Giant Branch (AGB) phase. Alongside the evolution of the orbit, the physical and chemical state of the planet's atmosphere will be affected by the intense radiation and outflow of the AGB star. At present, only one-dimensional descriptions exist of giant planets around AGB stars, based on parametrized analytical expressions, while such atmospheres require a 3D treatment with numerical hydrodynamics.

We present here 3D climate and 2D chemical disequilibrium models of a Jupiter-like planet around a Sun-like AGB star that take into account AGB stellar radiation. We use the MIT general circulation model to simulate the climate, and subsequently compute molecular abundances with a thermo- and photochemical kinetics code.

We find that the Jupiter-like planet could potentially develop a day-to-night temperature gradient with dayside temperatures well above 800 K. Similar to the climate of hot Jupiters around main-sequence stars, equatorial superrotation with wind speeds of several kilometers-per-second dominates the circulation pattern of the planet, and thus the planet could potentially become a "red-giant hot Jupiter" (RGHJ). Finally, we outline a pathway towards modeling the hydrodynamical impact of the dust-driven AGB outflow on the planetary atmosphere.

KEYWORDS AGB stars, giant planets, planet atmospheres, atmospheric composition, stellar wind

IAUS 370
#887

Analytical model of a multicomponent exoplanet magnetopause with variable particle distributions

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We propose a wide class of advanced models of an exoplanet magnetopause, i.e., an inner boundary of a magnetosheath region formed by a stellar wind colliding with a magnetosphere of an exoplanet. Namely, we find and analyze a set of analytical solutions to the Vlasov–Maxwell equations in the form of a superposition of arbitrary isotropic distribution functions of particle energy (Maxwellian, kappa, etc.), each multiplied by a Heaviside step function of one of the projections of the generalized momentum.

The solutions admit a shear of magnetic field lines and the presence of several ion components that have different effective temperatures and form different localized countercurrents with arbitrary densities and spatial shifts. As a result, the multiple non-monotonic changes of the magnetic field and asymmetric sign-changing current density profiles with several extrema are possible. The total thickness of the magnetopause is determined either by a gyroradius of particles with the highest energy content or a sum of shifts between the neighbouring current sheets.

The presented results go far beyond the scope of a magnetohydrodynamic approach and provide a kinetic-theory match between complex anisotropic distribution functions of particles. We carry out particle-in-cell simulations of the analytically constructed magnetopauses in 1D and 2D geometries. The stability of the simplest models is demonstrated, which is consistent with qualitative estimates of their stability with respect to Weibel-type perturbations.

The proposed models make it possible to interpret modern data of satellite observations of the multicomponent current sheets in the Earth magnetopause and to describe variety of the magnetopauses expected due to the flow-flow interaction in close-in exoplanets and host-stars.

KEYWORDS magnetopause, exoplanet, current sheet, non-Maxwellian plasma, kappa distribution, multicomponent plasma, collisionless plasma

IAUS 370
#885

Weibel mechanism of a coronal arch disruption due to an anisotropic electron injection: Analytical theory and particle-in-cell modeling

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We propose a mechanism for the disruption of an individual coronal arch on the Sun and stars of late spectral classes, which is based on the Weibel-type instability due to an injection of energetic (multi-keV) electrons into a sub-keV weakly collisional plasma. The injection is caused by an electric field created, for example, due to a plasma motion at the base of the arch or due to a generation of a powerful Alfvén wave in its lower part.

Energetic electrons reach the rarefied upper part of the arch, and their anisotropic velocity distribution leads to the Weibel instability producing small-scale (from meters to kilometers) current filaments (z-pinches) along the arch. As a result, a strong quasi-magnetostatic field directed mainly across the arch appears, the effective (anomalous) resistance of the plasma increases by several orders of magnitude, many synchronized nanoflares take place, a plasma is heated explosively, and a small-scale reconnection of magnetic field lines occurs. So, the balance between kinetic and magnetic pressures is disturbed, and a deformation of the large-scale magnetic field and a coronal mass ejection are possible.

We carry out analytical estimates of the linear and saturation stages of the Weibel instability. For the typical ranges of the plasma and arch parameters, we present the results of simulations by the particle-in-cell method (EPOCH code) of the long-term nonlinear development of this instability and processes caused by it. They lead to the destruction of an arch or to additional heating of the coronal plasma.

The aforementioned results substantiate the proposed mechanism of solar activity, give a consistent interpretation of a number of solar-flare features, and prompt explaining observations of the smallest-scale processes in coronal arches.

KEYWORDS solar flare, coronal arch, Weibel instability, z-pinch, PIC simulation

IAUS 370
#873

Solar Wind and Hydraulic Cycle

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In the solar system hydraulic cycle, water and gas are brought into inner planets through comets from the Kuiper Belt, and blow back to the Kuiper Belt by solar wind. When a comet collides with a rocky inner planet/moon, it releases the water and gas content onto the planet/moon. Vaporized water and gas are carried by solar wind all the way to the Kuiper Belt, where solar wind pushing and solar gravity pulling reaches equilibrium. In the Kuiper belt, the water vapor and gas refreeze, regroup, and reform into comets and fly back into the inner solar system to complete the hydraulic cycle. Earth is able to retain a significant amount of water and gas due to its mass, magnetic field, and distance from the sun with a somewhat diminished solar wind. The retained water and gas increases earth's mass, thus further enhancing water and gas retention. As the cycle repeats, the water and gas are more and more concentrated on earth due to the positive feedback loop. The comet collisions are random, the loss rate of water vapor and gas due to solar wind is more constant, thus the amount of water on earth fluctuates. Carbon dioxide level on earth can spike with random collisions of carbon dioxide rich comets. Like Earth, Mars or Moon also collides with comets, albeit less frequently. Thus, they can have a large quantity of water from time to time before solar wind strips them barren. Any terraforming effort on Mars, if ever successful, would be short lived. Overall trend for the solar hydraulic cycle is becoming less intense, as more and more water and gas are locked into planets. The trend is even more pronounced for inner planets as Jupiter takes more share of comet collisions.

KEYWORDS solar wind, hydraulic cycle, comet, Kuiper Belt

IAUS 370
#814

Lyα Radiative Transfer for Spatially Resolved Lyα Spectra from T Tauri star, TW Hydrae

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As the birthplaces of young protoplanets, the circumstellar disks surrounding T Tauri stars (TTSs) represent an important evolutionary link between star formation and potentially life-supporting planetary systems. TW Hya is one of the most iconic TTS with a face-on protoplanetary disk. The Lyman-Alpha (Lyα) line of neutral hydrogen is the most prominent emission line in the far UV spectra of TTSs. However, due to its resonant nature, its interpretation can be difficult and not many studies have focused on the Lyα observables of TTSs. In this talk, I will present recent results from our Lyα Monte-Carlo radiative transfer simulation including the spatial variation of the spectra – which I will compare to STIS slit observations of TW Hya. The model TTS in our simulation is composed of bipolar outflow wind, a rotating circumstellar disk, and a central Lyα source. I will show that with this simple model, the observational spectra are well fitted by the simulated spectra – but only when the projected size of the wind is larger than the size of the gas disk allowing Lyα to be scattered by atomic hydrogen. We will furthermore show that a substantial fraction of the observed flux consists of photons scattered off the disk. Thus, the disk component is crucial to explain the observed Lyα spectra from TW Hya. Our results show that Lyα radiative transfer models can provide constraints on physical parameters, such as the kinematics and geometry of the wind-gas-system, probing structures inaccessible by other means. Time provided, I will conclude with an outlook of studying multiple TTSs with similar methods, the current shortcomings of the model – and how they can be overcome.

KEYWORDS Radiative Transfer, T Tauri Star, Stellar Wind

IAUS 370

#620

To the dynamics of the two-body problem with variable masses in the presence of reactive forces

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The dynamics of celestial bodies with variable masses, especially the non-stationary stage of the gravitating system is little studied [1, 2]. We have considered the gravitational system consisting of two spherical celestial bodies with variable masses in the relative coordinate system. We studied the general case where the masses of bodies change non-isotropically at different rates, in the presence of reactive forces.

The problem was investigated by methods of perturbation theory based on aperiodic motion along a quasi-conic section [1-3]. We used perturbed motion equations in the Newton form equations with variables a, e, i, π, Ω, λ, which are analogs of Keplerian elements. The equations of perturbed motion of the osculating variables are obtained.

Averaging over the mean longitude we obtained the evolution equations of the two-body problem with variable masses in the presence of reactive forces. The evolution equations have an exact analytic integral a3e4=const.

The derived evolution equations of the two-body problem with variable masses in the presence of reactive forces will be used to study binary systems with variable masses.

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KEYWORDS variable masses, two-body problem, reactive force, perturbation theory

IAUS 370

#445

Planet migration in accretion discs in binary systems

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An accretion disc can be formed around a secondary non-evolved star in a binary system when the primary companion leaves the Main sequence and starts to lose mass with an enhanced rate due to slow stellar wind. We analyze accretion disc evolution and planetary migration in such discs around solar-like Main sequence stars in binary systems with evolved companions. A disc is formed from the stellar wind matter and its properties depend on the mass loss rate by the donor and the binary's parameters. We use a numerical model to study non-stationary discs with mass inflow on the whole disc surface within the Bondi radius during late stages of the primary evolution. Then, the migration path of a single planet embedded in such a non-stationary disc is determined by the migration rate varying in the course of the disc evolution.

In binary systems with initial separation $a\lesssim 80$~---~100 AU giant planets efficiently migrate in such discs and typically approach short distances from the host star where tidal forces become non-negligible.

Neptune-like planets can reach these internal parts of the system in cases when a donor is a relatively massive star (5-8 M$_\odot$) or in binaries with $a \lesssim 20$~AU. We conclude that in binaries, mass loss from the primary component at late evolutionary stages can significantly modify structure of a planetary system around the non-evolved secondary component, probably resulting in mergers of massive planets with the host star.

KEYWORDS exoplanets, wind accretion, binary systems, accretions discs, planet migration

IAUS 370

#344

Accretion Induced Collapse of White Dwarfs as an Alternative Symbiotic Channel to Millisecond Pulsars

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Recently, it has given extra motivation to the unresolved population of millisecond pulsars (MSPs) produced from the recycling process. This implies the apparent role of the accretion-induced collapse (AIC) in white dwarfs (WDs) in this issue. We find that the distribution of Nobs;orb closely follows an exponential distribution. We determine the best-fit value of the mean Nobs;orb, by fitting our data with an exponential distribution for MSP populations. As a the result, reaching the Chandrasekhar limit may cause the massive WD to explode as a Type Ia supernova (in the case of a CO WD) or to ignite the AIC process (in the case of an ONeMg WD; and possibly also in some CO WDs merging) producing peculiar MSP systems

KEYWORDS pulsars, white dwarfs, evolution:, kinematics and dynamics

IAUS 370
#321

Multicomponent Jet Simulations in T-Tauri

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Theoretical arguments as well as observations of Young Stellar Objects (YSO) support the idea of complex outflow structures. The inner stellar jet is the best candidate to account for the stellar spin down, while the disk wind sustains the observed high mass loss rate, thus playing a major role in the launching of powerful jets. RY Tau, for instance, is an extensively studied intermediate mass Classical T Tauri Star. Observational data also reveal that jets exist at small scale, the so-called microjets. RY Tau micro jet is well studied.

The goal of this work is to investigate how the various components interact with each other. We aim at studying the jet stability. We build global large scale simulations by mixing the stellar and the disk components. After studying separately the numerical evolution of each type of components, namely, the disk and stellar analytical wind solutions, we mix the two components inside the computational box. We additionally, replace the artificial polytropic equation linking pressure and density used to close the MHD equations by prescribing the local heating source, analytically. Then to mix the two components we use the sophisticated mixing technique developed by Matsakos et al. 2012, to ensure a divergence free magnetic flux. The time evolution of the 2.5D simulations is investigated with the PLUTO code analyzing the dynamics of the two-component jets, the modifications each solution undergoes, and the potential steady state reached.

KEYWORDS Accretion, magnetohydrodynamics (MHD), stars: T-Tauri, stars: winds

e-Talks

IAUS 370

#3274

Deciphering composition and winds in exoplanet atmospheres

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The elemental abundances and overall composition of exoplanet atmospheres are key measurements to understand the formation of planetary systems. In this context, a planet's atmosphere provides a fossil record of its primordial origins and controls its fate, size, appearance, and ultimately its habitability. However, it is crucial to decipher local and global climate properties, such as wind and global circulation systems, when estimating the composition of planets. We discuss observational programs that tackle the challenges of simultaneously extracting the chemical compound and the atmospheric dynamics of exoplanets. Our findings on the atmospheric composition and physical properties provide insights into the formation and evolution of planetary systems and enhance our understanding of our own Solar System's formation.

KEYWORDS exoplanets, atmospheres, winds, metallicity, planet formation, atmospheric dynamics, outflows

IAUS 370
#2867

Dust production around carbon-rich stars: the role of metallicity

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Most of the stars in the Universe will end their evolution by losing their envelope during the thermally pulsing asymptotic giant branch (TP-AGB) phase, enriching the interstellar medium of galaxies with heavy elements, partially condensed into dust grains formed in their extended envelopes. Among these stars, carbon-rich TP-AGB stars (C-stars) are particularly relevant for the chemical enrichment of the local and high-redshift galaxies.

We have investigated the role of the metallicity in the dust formation process from a theoretical viewpoint by coupling an up to date description of dust growth and dust-driven wind, including the time-averaged effect of shocks propagating into the circumstellar envelope, with the stellar evolutionary tracks computed with the FUNS code. We compare our predictions with observations of C-stars in our Galaxy, in the Magellanic Clouds and in the Galactic Halo, characterised by metallicity between solar and 1/10 of solar.

Our calculations explain the variation of acetylene molecules in the gas phase and dust content around C-stars derived from the IRS Spitzer spectra as a function of the metallicity. The wind speed of the C-stars observed at varying metallicity is fairly well reproduced by our description.

We predict the properties of the circumstellar envelope, including the wind speed, down to metallicities of 1/10 solar for different stellar masses, representative of diverse environments, including metal-poor star-forming dwarf galaxies. The model predictions can be tested with future observations performed by the Atacama Large Millimeter Array (ALMA) and the James Webb Space Telescope (JWST).

KEYWORDS

IAUS 370

#2616

Short-term variations of surface magnetism and prominences of the young Sun-like star V530 Per

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V530 Per is a solar-like member of the young open cluster α Persei, with an ultra-short rotation period (P ~ 0.32d). We report on two spectropolarimetric campaigns using ESPaDOnS, aimed at characterizing the short-term variability of its magnetic activity and large-scale magnetic field. We used time-resolved spectropolarimetric observations obtained in 2006 and 2018 and reconstructed the brightness distribution and large-scale magnetic field geometry of V530 Per through Zeeman-Doppler imaging. Using the same data sets, we also mapped the spatial distribution of prominences through tomography of Hα emission. We reconstruct, at both epochs, a large, dark spot occupying the polar region of V530 Per while smaller (dark and bright) spots were reconstructed at lower latitudes. The maximal field strength reached ~1 kG. The surface differential rotation was consistent with a smooth Sun-like shear $d\Omega = 0.053 \pm 0.004$ rad.d−1, close to the solar shear level. The prominence pattern displayed a stable component that was confined close to the corotation radius. In 2018, we also observed rapidly evolving Hα emitting structures, over timescales ranging from minutes to days. The fast Hα evolution was not linked to any detected photospheric changes in the spot or magnetic coverage.

KEYWORDS stars: magnetic field, stars: solar-type, starspots, stars: prominences, stars: individual: V530 Per

IAUS 370
#2388

Dispersal of protoplanetary disks by the combination of thermally and magnetically driven disk winds

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We investigate the long-term evolution and dispersal of protoplanetary disks focusing on the impact of disk winds. We specifically focus on the following two questions: (i) How does stellar evolution affect disk evolution? (ii) How do disks with weak turbulence disperse? On the first question, since photoevaporation (PE; thermally driven disk winds) is driven by stellar high-energy photons, we first derived the evolution of stellar XUV luminosities by combining stellar evolution simulations, stellar atmospheric models, and empirical relations from observations and theoretical considerations. From disk evolution simulations including a time-dependent PE model, we found that PE rates around low-mass stars are almost constant with time. On the other hand, those around intermediate-mass stars change dramatically: the X-ray PE rate decreases with time due to the stellar structure evolution (i.e., convective to radiative), whereas the FUV increases due to the increase of the stellar effective temperature. We conclude that stellar evolution is crucially important for the disk evolution around intermediate-mass stars. Our results show that the disk lifetime decreases with stellar mass, which has been suggested by observations. On the second question, both recent observations and theoretical studies have suggested protoplanetary disks are less turbulent. However, previous studies have suggested that a low viscosity results in a long (> 10 Myr) disk lifetime if the disk evolves with only viscous accretion and PE. In this study, we investigated the effects of MHD winds and wind-driven accretion. First, we investigated the disk evolution with these MHD processes and (inefficient) viscous accretion. We found that although these MHD processes significantly change the inner disk structure, the disks last long. On the other hand, if we also consider PE, the disk lifetime can be less than 6 Myr. We conclude that all three processes (i.e., PE, MHD winds, and wind-driven accretion) should be considered in a realistic disk evolutionary model.

KEYWORDS accretion, accretion disks, Protoplanetary disks, Pre-main sequence stars, Stellar evolution, stars: winds, outflows, Planet formation

IAUS 370

#2067

Shock breakout in type IIP supernovae and winds of red supergiant stars

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Massive stars drive stellar winds leading to reduced masses at the end of their lives when they may explode as supernovae (SN). In particular, red supergiants lose a lot of mass that form a circumstellar medium (CSM) around the star. If the star retains a substantial hydrogen envelope at the time of explosion, it displays characteristic light curves and spectra classifying the explosion as a type II Plateau SN, e.g. the nearby SN 2013ej. When the shockwave launched deep inside the star exits the surface, it probes this medium established by prior wind driven mass loss from the star. The bright electromagnetic display accompanying the shock breakout is influenced by the properties of the star and also scripts the history of mass loss that took place from the star, especially during its late stages of nuclear evolution. What kind of supernovae originate from which kind of stars has been a long-standing question. Here we investigate with simulation codes MESA and STELLA the inverse problem: what kind of SN radiative display results from a set of progenitors that we evolve from the main sequence to the core collapse phase. We use diverse evolutionary inputs, including mass loss, which may be very intense in the later stages of central nuclear evolution. We simulate with different internal convective overshoot and compositional mixing scenarios inside the stars and two sets of mass loss schema, one of which is the standard "Dutch" scheme and another, a hypothetical enhanced, episodic mass loss at a late evolutionary stage. The shock breakout from the star shows closely time separated double peaked bolometric light curves for the Dutch wind mass loss, as well as high velocity ejecta with miniscule mass accelerated during the shock breakout. We also contrast the breakout flash from an optically thick CSM with that of the rarified medium established by Dutch wind. We describe how the multi-group photon spectra of the breakout flashes differ.

KEYWORDS Massive stars (732), Stellar mass loss (1613), Core-collapse supernovae (304), Type II supernovae (1731), Computational methods (1965), Stellar evolutionary models (2046)

Statistical properties of cold circumstellar envelops observed in NESS-NRO

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The asymptotic giant branch (AGB) represents the final stage in the evolution of low- and intermediate-mass stars. Mass loss from AGB stars dominates the evolution of light elements (e.g., carbon and nitrogen) and s-process elements in the present-day our Galaxy. Among those elements, carbon is dredged up from near the central core to the stellar surface by the convection caused by thermal pulses. This repeated dredge-up process gradually changes the 12C/13C abundance ratio in the circumstellar envelopes. The issues of this process are its efficiency and the mechanism determining the mass loss rate (MLR). The MLR of thermally pulsating AGB stars is generally higher than that of hydrogen burning, forming a shell-like gas/dust distribution around the star. Therefore, by determining the 12CO/13CO ratio as a probe of the dredge-up efficiency over the entire envelopes, the issue can be constrained.

The Nearby Evolved Stars Survey (NESS) addresses several issues including this dredge-up issue using a volume-complete sample of ~850 Galactic evolved stars within 3 kpc with multi-telescope. Primarily using the James Clerk Maxwell Telescope (JCMT), these sources have been observed in the CO J = 2→1 and 3→2 rotational lines, and the sub-mm continuum. In addition, to reveal more extended cold gas distribution, we have carried out mapping observations (18 sources) and staring observations (207 sources) of the 12CO and 13CO J = 1→0 lines using the 45m radio telescope of the Nobeyama Radio Observatory (NRO). The angular resolution of this NESS-NRO observation is the same as that of the JCMT observation in the CO J = 3→2 line. Here, we mainly present the results of the NESS-NRO. The mapping observations revealed that the Brightness distribution in the J = 1→0 line is more extended than that in the J = 3→2 line. Also, in the three sources, the 12CO/13CO intensity ratio changed along the radial direction from the star. We present the discussion of this change of intensity ratio, statistical results from staring observations, and the discovery of object with aspherical envelop.

KEYWORDS AGB and post-AGB, mass-loss, winds, outflow, Carbon Monoxide

IAUS 370

#1799

Stellar Midlife Crisis: Subcritical Magnetic Dynamos of Solar-like Stars Explains the Break-down of Gyrochronology and the Transition to a Magnetically Inactive Future

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Recent observations indicate that stellar gyrochronology relations break down at about the Sun's age suggesting that middle-aged, solar-like stars transition to a magnetically inactive future. Based on dynamo simulations of stellar magnetic activity, we provide a theoretical basis for these intriguing observations which also reproduces the observed bimodal distribution of sunspot numbers, but only for subcritical magnetic dynamos. We argue that the aging of solar-like stars makes the magnetically-weak subcritical dynamo regime readily accessible. Weak magnetic field production in this regime compromises wind-driven angular momentum losses thus influencing stellar spin-down. Our study provides a self-consistent, unifying physical explanation for a diversity of solar-stellar phenomena such as why stars beyond their midlife do not spin down as fast as in their youth, the break-down of stellar gyrochronology relations, the observed bimodal distribution of sunspots and recent findings suggesting that the Sun may be transitioning to a magnetically inactive future.

KEYWORDS Stellar Winds, Stellar Magnetism, Stellar Rotation, Stellar Gyrochronology, Stellar Dynamo, Stellar Evolution, Sunspots

IAUS 370

#1631

UNDERSTANDING ACCRETION IN HIGH MASS X-RAY BINARIES: THE CASE STUDY OF VELA X-1

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Strong winds from massive stars are a topic of interest to a wide range of astrophysical fields, e.g., stellar evolution, X-ray binaries or the evolution of galaxies. In High-Mass X-ray Binaries the presence of an accreting compact object can strongly influence the wind flow, allowing to study stellar wind properties in situ. As the compact object, either a neutron star or a black hole, moves through the dense stellar wind, it accretes material from its donor star and therefore emit X-rays. The wind will therefore be highly unstable revealing a very rich phenomenology.

We discuss recent developments on the accretion models in high mass X-ray binaries, ranging from detailed descriptions of the wind acceleration to modelling of the structure of the flow of matter on a global (binary-wide) scale and on a very close to the neutron star scale as well. The latter can show the potential formation of a wind-captured disc beyond the neutron star's magnetosphere in some cases. Such a structure remains to be observed but its indirect signatures through jets or the torques it applies on the neutron star could well be within our observational grasp.

We compare our simulation results with the most well studied object, i.e., the eclipsing high mass X-ray binary Vela X-1. Vela X-1 consists of an accreting X-ray pulsar orbiting an early type supergiant with an orbital period of about 9 days. It was discovered as an X-ray source by the Uhuru satellite and it has been observed since then by every X-ray observatory. Due to its brightness and variability as well as the large observational archives, Vela X-1 is the Rosetta stone for studies of wind accretion onto neutron stars.

KEYWORDS Massive, Stars, Observation, X-rays, stellar winds, hydrodynamic, simulations

IAUS 370
#1624

Variable and Supersonic Winds in the Atmosphere of an Ultrahot Giant Planet

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Hot Jupiters (HJs) present an extreme case for exploring the conditions that regulate planetary atmospheres because they experience intense irradiation from their host stars that induce global-scale winds. General circulation models (GCMs) of HJ atmospheres predict day-to-nightside winds (winds flowing from the side of the planet facing its host star to the side facing away from the star) and equatorial jets (winds that entirely circulate around the planet) with speeds on the order of a few km/s. We apply high-resolution transmission spectroscopy using the PEPSI spectrograph on the Large Binocular Telescope to empirically constrain supersonic ~10 km/s day-to-nightside winds traced by Fe II features in the atmosphere of KELT-9 b, an ultra-hot Jupiter (UHJ) that remains to-date the hottest known planet. Reconciling our findings with archival HARPS-N datasets suggests multi-epoch variability ~5-8 km/s over timescales between weeks to years. We compare with the UHJ KELT-20 b to demonstrate the exceptional nature of KELT-9 b's atmospheric dynamics. A qualitative evaluation of our measured wind velocities and variability against current UHJ GCMs reveals that KELT-9 b poses unique challenges for validating giant planet atmospheric models.

KEYWORDS exoplanet atmospheres, atmospheric variability

Gap opening by planets in discs with MHD winds

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Planets are known to open deep gaps in protoplanetary discs when their mass exceeds a gap opening mass, Mgap. Here we use one- and two-dimensional simulations to study planet gap opening in discs with angular momentum transport powered by MHD disc winds. We parameterise the efficiency of the MHD disc wind angular momentum transport through a dimensionless parameter αdw, which is an analogue to the turbulent viscosity αv. We find that MHD disc winds are much less efficient in counteracting planet tidal torques than turbulence is. For a disc in which αdw~αv, Mgap is determined by the disc viscosity rather than the wind. If turbulence is as weak as αv~10−4 then Mgap is a factor of a few to ten smaller than previously derived for discs with αv≥10−3 unless αdw≫10−2. We generalise the well-known Crida et al. (2006) gap opening criterion for turbulent discs to evaluate Mgap for any values of αv and αdw. We conclude that if MHD disc winds are the main driver of angular momentum transfer, then formation and evolution of planets of mass greater than about one Earth mass is very different from that in the viscous disc models. These effects must be taken into account in future population synthesis models of planet formation.

KEYWORDS planet-disc interactions, protoplanetary discs, planets and satellites: formation

IAUS 370

#1475

Stellar prominences as an additional mass loss mechanism to the wind in young stars

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A star's evolution is governed by the stellar wind, the mechanism by which mass and angular momentum are expelled from the star. Much of our understanding of stellar winds comes from theoretical studies, since observing these winds, which have very low densities, is so challenging. These studies, however, typically under predict the spin down of stars when compared to observations. We propose that an additional process - the formation and ejection of "slingshot prominences" - could be contributing to this spin down. These slingshot prominences are cool condensations of coronal plasma that are observed to be supported at great heights above the stellar surface by strong magnetic fields. They form on rapidly rotating stars and when ejected remove mass and angular momentum. We have used observations of stellar surface magnetic fields to model the magnetic field within the corona. From this, the locations, masses, and mass loss rates of prominences supported within this field are calculated. We plot the prominence mass loss rate per unit area against X-ray flux, and find that it scales with F_X^(1.32), which is very close to the observationally derived value for stellar winds. These results suggest that prominence ejection may carry away substantial mass loss and contribute to stellar spin down at some points in a star's evolution.

KEYWORDS low mass stars, mdwarfs, winds, young stars, mass loss

IAUS 370
#1233

Clumping and X-Rays in Cool B-Supergiants

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After a few million years, massive stars quickly evolve off the main sequence into a regime where we find so-called B supergiants (BSGs). In this region of the Hertzsprung–Russell diagram, we find stars of different evolutionary origins, raising fundamental questions about the role of BSGs: Are they hydrogen- or helium-burning objects? Are they evolving redwards or bluewards? Are they, as typically assumed, direct descendants of main-sequence stars or are they actually post-red supergiant objects?

To correctly identify the role(s) BSGs occupy in the evolution of massive stars, it is essential to analyze the spectra of these objects and identify their stellar and atmospheric parameters. In this work, we focus on the so far rarely studied cooler BSGs - i.e. with spectral types later than B1, corresponding to temperatures below the so-called Bi-Stability Jump region. Using CMFGEN and PoWR, we performed a quantitive analysis including the effects of clumping and shock-heated X-rays in the wind. By including these physical ingredients in our models, we were able to reproduce the combined UV and optical spectra of our sample stars, overcoming previous difficulties reported in the literature to explain important UV profiles of higher ionization stages.

Our results show that both X-rays and clumping need to be taken into account for cooler BSGs, but their properties are quite different to those in hotter BSGs. For our targets, we derive Lx/Lbol ratios considerably lower than the typical 10-7. This in line with the observed X-rays for such objects, but also demonstrate that X-rays as such cannot be neglected in cooler BSGs. Concerning clumping, our obtained parameters reveal that cooler BSGs have significantly smoother winds than hotter BSGs, confirming recent hydrodynamical predictions. We discuss some potential consequences of our investigation for the B supergiants in the context of wind bi-stability in massive stars and implications for stellar evolution.

KEYWORDS massive stars, B stars, B supergiants, stellar winds, clumping, X-ray, stellar evolution

IAUS 370

#1220

Abundances of bioessential elements using HARPS spectra

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Since the discovery of the first exoplanet in 1995 by Mayor and Queloz, we have witnessed an accelerated increase in the number of exoplanets detected - surpassing the mark of 5000 (NASA Exoplanet Archive, acessed on 2022/03/29). These discoveries, associated with an increasingly detailed characterization of exoplanets and their host stars, have expanded the frontiers of Astrobiology and allowed even more comprehensive studies on the formation and habitability of planets and the distribution of life in the Universe. When we think about life as we know it, we are naturally driven to think of the most frequent elements in the composition of organisms: the CHNOPS (carbon, hydrogen, nitrogen, phosphorus and sulfur). Though they are bio-essential elements for life on Earth, they are poorly explored in abundance studies in general. Thus, for a better understanding of the structures of terrestrial planets, habitability and life, it is fundamental to have more homogeneous and precise abundances for these elements for a large number of stars. Therefore, in this work, we derived abundances of C, O and S, poorly explored elements in Astronomy, focusing on stars with detected exoplanets, in order to investigate the possible relation between these elements and the formation and habitability of terrestrial planets, to contribute for a better understanding of the necessary conditions for life to emerge. Our homogeneous abundances will also contribute to the expansion and update of the Hypatia Catalog, allowing studies in other areas, such as chemical evolution of the Galaxy. We present results for abundances of Fe, C, O and S for ~500 solar-type stars and their relationships to the presence of terrestrial planets.

KEYWORDS stars: abundances, stars: low-mass, astrobiology, exoplanets, techniques: spectroscopy

IAUS 370
#1161

Rapidly orbital precession of the eclipsing binary HS Hydrae

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Objective: Our goals are to analyze the long-term variability and to reveal the factors for change of the orbital inclination and angular-momentum losses in eclipsing binary star HS Hya.

Methods. We obtained the CCD photometric observation series of eclipsing binary system HS Hya at High-altitude Maidanak Astronomical Observatory in Uzbekistan and performed analysis of the light curves of HS Hya and their long-term evolution. We collected all available photometric data since its discovery, and the light curves were analyzed with a special focus on evolution of system's orbital inclination and angular-momentum losses. We also digged out and analyzed the data on HS Hya obtained by TESS mission.

Results. Based on deep analysis of all observational data we found that the system undergoes a rapid change of inclination of its orbit. Since its discovery until novadays, i.e. between 1964 and 2019, the system's inclination has changed by more than 17.5 angular degrees. Our analysis has shown that eclipses in this system will reappear again in 130 years. Our observational data analysis also showed that the amplitude of variability due to the ellipticity of one of the components is not conserved.

Conclusions. The eclipsing binary star HS Hya before our investigation belonged to the detached binary systems and classified as EA type variable star on the basis of previously known observational data. The new analsys of all existed data including our and TESS data revealed that in addition to the eclipses the binary system has superposition of different modes of variability including an elipsoidal variation out of eclipses. The last may be due to the elliptical shape of one of the members of the system. We also suppose that HS Hya has a starspots on a surface of at least one of the companion stars as well as that there are the strong flows and winds in the system. At present we found only 13 binary systems with change in the orbital inclination, 9 of which are EA type binaries.

KEYWORDS binary star, CCD photometry, TESS data, modes of variability, evolution of orbital inclination, angular-momentum losses, flows and winds

IAUS 370
#1152

Prospecting Clumpy wind Accretion in the IGR J17252-3616 with XMM-Newton

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Supergiant X-ray binaries are a class of X-ray binaries consisting of a Neutron star accreting from the wind of a supergiant companion star. A peculiar class of the supergiant X-ray binaries is Supergiant Fast X-ray Transients (SFXT), characterized by significant variability in the X-ray band and usually ascribed to accretion from a clumpy stellar wind. In this work, we aim to probe clumpy wind in the obscured sgHMXB IGR J17252-3616 through employing a systematic approach reported by Bozzo et al. 2017. Taking advantage of the instruments onboard the XMM-Newton telescope, we will use ten XMM-Newton archival observations to conduct a hardness-resolved spectral analysis on a timescale of a few hundreds of seconds. Consequently, this will lead to capturing the spectral variations that are theoretically associated with the presence of dense structures in the stellar wind interacting with the X-rays from the compact objects.

KEYWORDS Xray binaries, Accretion, IGR J17252-3616, SFXT, Clumps

IAUS 370
#1143

Pile-up treatment and spectral analysis of a HMXB using XMM-NEWTON

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High-mass x-ray binaries (HMXBs) are astrophysical systems that consist of a compact object and a companion star. Because of the massive gravitational pull of the compact object, matter from the companion star falls into it, creating an accretion disk. Such accretion disks are formed via stellar wind. We aim to study the HMXB IGR J18027-2016 through spectral analysis, which can tell us how fast the material moves and give us information about the stellar wind.

Using archival data provided by the XMM-NEWTON mission, we aim to produce a spectrum of IGR J18027-2016 and fit it into an appropriate model. The XMM-Newton telescope provides six archival observations of IGR J18027-2016. Unfortunately, three of the six observations suffer from pile-up. Pile-up is when more than one photon from a bright X-ray source hits a pixel or adjacent pixels of the craft's camera during one readout cycle resulting in photon loss, energy distortion, and pattern migration, causing the spectra to be distorted.

The source has been studied before, but very little literature is available dealing with its pile-up effects. Therefore, we plan to explore these pile-up effects of the XMM-NEWTON cameras and try to resolve them to produce a better spectrum.

KEYWORDS XMM-NEWTON, HMXB, pile-up, IGR J18027-2016

IAUS 370

#1057

On the making of a PN: the interaction of a multiple stellar wind with the ISM

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NGC 7293, the Helix nebula, represents one of the rare instances in which theoretical predictions of stellar evolution can be accurately tested against observations since the precise parallax distance and the velocity and proper motion of the star are well known.

We present numerical simulations of the formation of the Helix PN that are fully constrained by the (inferred) progenitor stellar mass, stellar evolution history, and star-interstellar medium (ISM) interaction.

We have followed the evolution of the star from the early Asymptotic Giant Branch (AGB) phase to the PN stage and modeled the density and kinematical evolution of the expanding shells considering the observed relative motion of the star.

In the simulations, multiple bow-shock structures are formed by fragmentation of the shock front where the direct interaction of the stellar wind with the ISM takes place. The observed opening angle of the bow-shock matches that obtained using a 40 km/s velocity for the relative star-ISM motion; and most important, the outer nebular size (or PN halo) is the result of the mass-loss associated to the last thermal pulse only, i.e. the last less equal than 50000 yr of evolution on the AGB phase.

The same progenitor at rest would produce a PN twice the size of the Helix.

We argue that the PN-ISM process gives an adequate, and simple explanation for the morphological features present in the outer halo of the Helix nebula and that the process that shaped the characteristic helical morphology of the main nebular shell must take place at the very end of the last thermal pulse just before, or simultaneously, with the onset of the fast wind. Furthermore, we consider that the molecular knots and cometary tails can be naturally explained by interacting winds with different ionization fractions, shell fragmentation instabilities, or by swept-up shells overruning clouds.

KEYWORDS stars: AGB and post-AGB, stars: winds, outflows, stars: circumstellar matter, stars:mass loss, ISM bubbles, ISM: planetary nebulae

Evolution equations of the multi-planetary problem with variable masses

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The study of dynamical evolution of planetary systems is actual topic in astronomy. Researching of dynamics of exoplanets [1] in the non-stationary stage of its formation gives us the opportunity to determine further evolutionary tracks. The influence of the variability of the masses of celestial bodies is explored on the dynamic evolution of planetary systems, considering that the masses of bodies change isotropically with different velocities. The laws of masses are considered be known and given functions of time. The differential equations of motion of n+1 bodies in the relative coordinate system are given in the works [2-3]. The methods of canonical perturbation theory are used, which developed on the basis of aperiodic motion over a quasi-conical section [2].

The Wolfram Mathematica package is used in the expansion of perturbing functions into series. Secular perturbations of Poincare elements are defined as solutions of a system of 4n linear differential equations. The evolutionary equations are obtained.

The three-planet exosystem K2-3 is considered in the non-stationary stage of its evolution. The secular perturbations of Poincare elements are described as system of 12 linear non-autonomous differential equations. Further, the evolutionary equations are investigated by numerical method.

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KEYWORDS dynamic evolution, multi-planetary problem, exoplanetary system, canonical perturbation theory, the Poincare elements, evolutionary equations, variable mass

IAUS 370

#568

X-ray view of colliding winds in WR 25

Bharti Arora[1]

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The long-term behavior of a colliding wind binary WR 25 is presented using archival X-ray data obtained over a time span of ~16 years. The present analysis reveals phase-locked variations repeating consistently over many consecutive orbits of the source (with binary orbital period ~208 days). A significant deviation of the X-ray flux with respect to the 1/D trend (D is the binary separation) close to periastron passage has been observed. WR 25 is one of the very few binary systems with such a long orbital period which shows the presence of a strong hysteresis effect in its X-ray emission. This may occur due to the shifting of the adiabatic wind collision to the radiative regime in that part of the orbit. Different mechanisms responsible for the switching of cooling mechanisms of plasma will be discussed. Further, no signature of X-ray emission in 10.0-79.0 keV energy range from WR 25 is observed by NuSTAR. This pushes WR 25 in the list of doubtful massive binaries which may or may not show the presence of particle acceleration in their wind collision region unless observed with instruments having better hard X-ray sensitivity than the present ones.

KEYWORDS WR binaries, X-rays, colliding winds, Particle acceleration

IAUS 370
#564

X-ray view of colliding winds in WR 25

Bharti Arora[1]

[1]Astronomy and Astrphysics, Aryabhatta Research Institute of Observational Sciences, India

The long-term behavior of a colliding wind binary WR 25 is presented using archival X-ray data obtained over a time span of ~16 years. The present analysis reveals phase-locked variations repeating consistently over many consecutive orbits of the source (with binary orbital period ~208 days). A significant deviation of the X-ray flux with respect to the 1/D trend (D is the binary separation) close to periastron passage has been observed. WR 25 is one of the very few binary systems with such a long orbital period which shows the presence of a strong hysteresis effect in its X-ray emission. This may occur due to the shifting of the adiabatic wind collision to the radiative regime in that part of the orbit. Different mechanisms responsible for the switching of cooling mechanisms of plasma will be discussed. Further, no signature of X-ray emission in 10.0-79.0 keV energy range from WR 25 is observed by NuSTAR. This pushes WR 25 in the list of doubtful massive binaries which may or may not show the presence of particle acceleration in their wind collision region unless observed with instruments having better hard X-ray sensitivity than the present ones.

KEYWORDS WR binaries, X-rays, colliding winds, particle acceleration

IAUS 370

#531

Mass loss in the atmosphere of the hottest ultra-hot Jupiter

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Ultra-hot Jupiters have become prime targets for atmospheric characterisation. KELT-9b is the hottest of the known ultra-hot Jupiters and both hydrogen Balmer lines and metal line features have been detected in transmission and/or emission. I will show how non-local thermodynamical equilibrium (NLTE) effects drive the temperature-pressure structure of KELT-9b's atmosphere and that NLTE effects must be taken into account to reproduce the observations. The NLTE model has even been used to inspire and guide the detection of neutral oxygen in the planetary atmosphere. I will show how this model has enabled the direct observational identification of NLTE effects in the atmosphere of KELT-9b and how this tightly constraints atmospheric mass-loss rates and wind velocities.

KEYWORDS ultra-hot Jupiters, KELT-9b, mas loss

IAUS 370
#294

Local ionization rates by magnetic reconnection events in TTauri disks

Valentin Brunn[1]

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Magnetic reconnection is one of the major particle acceleration processes in space and astrophysical plasmas. Low-energy supra-thermal particles emitted by magnetic reconnection are a source of ionization for circumstellar disks, influencing their chemical, thermal and dynamical evolution. The aim of this work is to study how energetic particles can propagate in the circumstellar disk of a TTauri star and how they affect the ionization rate of the disk plasma. To this end, we have collected experimental and theoretical data on the cross sections for the production of H+, H2+ and He+ by electrons and protons. Starting from theoretical injection spectra of protons and electrons emitted during magnetic reconnection, we have calculated the propagated spectra in the circumstellar disk considering the relevant energy loss processes. We have conducted a comparison of the ionization rates by energetic particles in different magnetic configurations considering the physical properties of the flares as observed by the Chandra satellite for a sample of sources in the Orion Nebula (COUP). We have tested the ionization rates obtained for a disk which chemical equilibrium is calculated by the chemistry PRODIMO code. We find that energetic particles could be a strong source of local ionization in the circumstellar disk close to the star.

KEYWORDS cosmic rays, protoplanetary disks, low-mass stars, magnetic reconnection, stellar flares

IAUS 371

Honoring Charlotte Moore Sitterly: Astronomical Spectroscopy in the 21st Century

Invited & Contributed Talks

IAUS 371

#2335

Molecular processes relevant for astrophysics: theoretical studies

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More than 240 different molecules have been detected in interstellar space, but how do they form? And what limits their abundances? How can astronomers use them as diagnostics for the physics of the environment in which they are found, such as temperatures, densities, mass, and cosmic ray ionization rate? Extracting this information requires detailed knowledge of the different molecular processes between atoms and molecules that can take place, in addition to the spectroscopy needed to identify them. Some reaction rates can be measured in the laboratory, but others can only be provided by theoretical calculations. A brief overview of a number of key theoretical studies of molecular reactions will be presented, with a focus on photodissociation processes of molecules.

KEYWORDS Molecular processes, Interstellar clouds, Photodissociation

Collisional rate coefficients for astrophysics

Alexandre Faure[1]

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At interstellar pressures, inelastic collisions cannot maintain a local thermodynamical equilibrium (LTE). Atomic and molecular populations therefore do not follow a simple Maxwell-Boltzmann distribution and non-LTE spectra are the rule rather than the exception. Accurate state-to-state collisional data are thus crucial for a quantitative interpretation of spectroscopic observations. In recent years, considerable progress has been made in quantum calculations of collisional rate coefficients for a variety of targets, types of transitions and projectiles. For a few benchmark species like CO, detailed comparisons between theory and experiment were also carried out at the state-to-state level and in the quantum regime. I will highlight recent results and describe current computational efforts to extend these advances to ever larger targets and new environments (e.g. stellar envelopes or cometary atmospheres).

KEYWORDS Interstellar medium, molecular collisions, quantum scattering theory, state-to-state energy transfer

IAUS 371

#763

Databases of atomic and molecular data

Marie Lise Dubernet[1]

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The building of on-line atomic and molecular databases for astrophysics and for other applications fields have started from the beginning of the internet. Those have encompassed different forms: private databases exposing their own data, databases providing collected data from the refereed literature, databases providing evaluated compilation, databases providing repositories for individuals to deposit their data and so on. Those were and are the replacement for literature compilations with the goal to provide a better data service to the users communities. That work involved not only scientific work on the data, but also the characterization of the data, which could be seen as the start of the "standardization" of metadata and of the relations between metadata, as it has recently been developed in different communities.

This talk aims at providing an overview of the atomic and molecular databases ecosystem which is available to the astrophysical community. It will describe the issues linked to format and data descriptions, to data exchanges and usage in astrophysical tools and codes. It will outline the various organizations of communities that provide access to atomic and molecular data and databases. Finally it will address long term sustainability issues linked to the scientific quality of the provided data and to their long term availability.

Acknowledgement : This talk is fueled by the work performed by different actors over the years : databases, institutions such as the IAEA, the NIST, the IUPAC, infrastructures such as the VAMDC and more recently from the IAU B5 commission and its working groups, not forgetting the past history of other commissions linked to atomic and molecular data at the IAU.

Acronyms : IAEA : International Atomic Energy Agency (iaea.org); NIST : National Institute of Standards and Technology (www.nist.gov); IUPAC : International Union of Pure and Applied Chemistry (iupac.org); VAMDC : Virtual Atomic and Molecular Data Centre (vamdc.org); B5 commission on Laboratory Astrophysics

KEYWORDS Database, Atoms, Molecules, Data exchange, Infrastructure, Standards

IAUS 371
#808

LIDA: The Leiden Ice Database for Astrochemistry

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[2]*Laboratory for Astrophysics, Leiden University, Netherlands*
[3]*Nordita, KTH Royal Institute of Technology and Stockholm University, Sweden*

Atomic and molecular data obtained from experiments are crucial for deriving meaningful information of astrophysical environments such as densities, temperatures and chemical abundances. In this regard, electronic databases have been of utmost importance for providing fundamental information in an organized and accessible way. In the last decades, dedicated databases for the gas phase (e.g., CDMS [1], LAMDA [2], BASECOL [3] and KIDA [4]), and solid-phase molecules (e.g., Jena [5], NASA/Ames [6] and SSHADE [7]) have allowed important discoveries about the chemistry in star- and planet-forming regions. In this context, the Leiden Ice Database for Astrochemistry (LIDA; https://icedb.strw.leidenuniv.nl/), has played for years an important role by supporting the studies of many molecules in the solid-phase toward protostars (e.g, H2O, CO, CO2, CH4, NH3 and CH3OH, OCN-, NH4+, OCS). Envisioning the observations that will be obtained with high-class telescopes (e.g., James Webb Space Telescope - JWST, Extremely Large Telescope), LIDA has been upgraded in several aspects to continue providing key support to the study of inter and circumstellar ices. First, we have made publicly available the infrared spectra of several molecules, including the major ice components and complex organic molecules. Altogether, LIDA host more than 1100 infrared spectra of ices that mimic different astrophysical conditions. Additionally, LIDA also hosts UV-vis optical constants of ices measured in Leiden and online tools. They allow the calculation of the mid-infrared complex refractive index of ices and also the creation of protostar synthetic spectra. LIDA has also been improved with many dynamical visualization tools, and a 3D molecule viewer linked to public databases of molecular properties. LIDA is a deliverable of Ice Age, an Early Release Science program of JWST. The upgrades on LIDA will benefit multiple ice observations in the next years and decades.

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KEYWORDS astrochemistry, molecular data, infrared, ices

IAUS 371
#2534

NIST-LANL Lanthanide Opacity Database

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Kilonovae (or macronovae) are astronomical transient events that produce electromagnetic emission from matter ejected by the merger of two neutron stars or a neutron star and black hole. The first kilonova associated with gravitational waves (detected by LIGO/Virgo) was observed in 2017, in signals that spanned the electromagnetic spectrum. This was a significant discovery in astronomy, galvanizing research into the broad range of physics underlying neutron star mergers.

Radiative opacities for a significant fraction of the elements in the periodic table are required to model the light curves and spectra produced by kilonovae. A first set of opacities has been calculated, under the assumption of local thermodynamic equilibrium (LTE), for the lanthanide elements with atomic number $57 \leq Z \leq 70$ (Fontes et al, Mon. Not. Roy. Astron. Soc. 493, 4143 (2020)). This set has then become the source of data for the newly developed lanthanide opacity database which is the result of a collaborative effort between LANL and NIST. In this talk we will present the basic assumptions for data calculations, the data coverage, the structure of the database, and its user interface.

KEYWORDS opacity, kilonova, lanthanides, database

IAUS 371
#1981

The state of solar analyses, and solar and stellar spectroscopy and solar models

Maria Bergemann[1]

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Our understanding of planets, stars, and galaxies is intricately tied to the knowledge of detailed chemical composition of the Sun and stars in the Milky Way. In this talk, I will focus on the frontiers of stellar spectroscopy in the 2020s, from the perspective of models and observations. Major progress in the quality and quantity of stellar spectra is expected with next generation facilities, such as 4MOST, WEAVE, and SDSS-V. In parallel, advances in computational astrophysics have allowed to bridge the gap between data and 3D non-LTE spectral models based on radiation-hydrodynamics simulations of sub-surface convection. Atomic and molecular data used in these models set the floor to the accuracy of atmospheric retrievals for stars. I will demonstrate how new data and new models drive progress in the areas that rely on stellar parameters and chemical composition of stars. These include studies of exoplanets, solar interior and stellar evolution, and stellar populations in the Galaxy. I will close with a personal view of perspectives opening with large astronomical facilities of the next decade.

KEYWORDS Stars, Spectroscopy, Stellar atmospheres, Atomic data, Fundamental parameters, Chemical composition, Stellar populations

IAUS 371

#1629

Improving planetary atmosphere characterization by 3D NLTE modeling of the stellar centre-to-limb effect

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[1]Astronomy, Stockholm University, Italy

The center-to-limb variation (CLV) of the stellar lines across the stellar disk is an important effect for planetary transit spectroscopy. Indeed the variation of spectral line profiles when the planet transits different part of the stellar disk can affect the determination of elemental abundances in the planetary atmospheres, as shown by Yan et al. (2017).

Accurately modelling the CLV effect of planet-host stars is fundamental to better characterize the planetary transmission spectrum and to correctly detect and measure abundances of atmospheric species.

However, we know that the commonly used 1D plane-parallel LTE atmosphere models fail to reproduce spatially resolved observations of the solar disk. 3D hydrodynamic models and non-LTE line formation is required for an accurate modelling of the CLV effect.

So far, the best studied atomic lines in transit spectroscopy are the Na D lines and the NIR K resonance lines. In this talk I will present new results regarding the modelling of these lines in the Sun using 3D NLTE radiative transfer and discuss possible implications for transit spectroscopy.

KEYWORDS planetary atmosphere, center-to-limb variation, radiative transfer, spectroscopy

IAUS 371
#2611

Comparative high-resolution spectroscopy of M dwarfs: Exploring non-LTE effects

Terese Olander[1]

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M dwarfs are key targets for high-resolution spectroscopic analyses due to a high incidence of these stars in the solar neighbourhood and their importance as exoplanetary hosts. Several methodological challenges make such analyses difficult, leading to significant discrepancies in the published results. We compare M dwarf parameters derived by recent high-resolution near-infrared studies with each other and with fundamental stellar parameters. We also assess to what extent deviations from local thermodynamic equilibrium (LTE) for Fe and K influence the outcome of these studies. This was done by carrying out line formation calculations based on a modern model atmosphere grid along with a synthetic spectrum synthesis code that treats formation of atomic and molecular lines in cool-star atmospheres including departures from LTE. We use near-infrared spectra collected with the CRIRES instrument at the ESO VLT as reference observational data.

We find that the effective temperatures obtained by the different studies mostly agree to better than 100 K. A much worse agreement is seen for the surface gravities and metallicities. We demonstrate that non-LTE effects are negligible for Fe I in M-dwarf atmospheres but are important for K I. These effects, leading to K abundance and metallicity corrections on the order of 0.2 dex, may be responsible for some of the discrepancies in the published analyses. Differences in the temperature-pressure structures of the atmospheric models may be another factor contributing to the discrepancies, in particular at low metallicities and high effective temperatures. In high-resolution spectroscopic studies of M dwarfs attention should be given to details of the line formation physics as well as input atomic and molecular data. Collecting high-quality, wide wavelength coverage spectra of benchmark M dwarfs is an essential future step.

KEYWORDS M dwarf, high-resolution spectroscopy, Non-LTE, stellar parameters

IAUS 371
#1135

Contribution of small telescopes at the oukaimeden observatory in Morocco to study Atmospheric dynamics and shocks in variables stars RR Lyr and R sct

Abdelmajid BENHIDA[1]

[1]Physic, Cadi Ayad University, Morocco

Through Spectroscopy, we aim to develop the field of pulsating stars, especially the atmospheric dynamics of high amplitude pulsators such as RR Lyr and Rscuti, in order to establish new models of the mechanical and thermal behavior of their atmospheres (shock waves, relaxation time, energy loss...)

We used 2437 high-resolution spectra over a total of 81 nights from made with the spectrograph Eshell during years 2013 and 2015 runs from Oukaïmeden observatory in the High Atlas mountains (Morocco) completed with made with the spectrograph ELODIE (Haute Provence observatory, France) during years 1994-1997. Adetailed analysis of line profile variations over the whole pulsation cycle is performed to detect the possiblepresence of helium emission during these two surveys separated by 21 years. Shock wave velocity and lines intensity were used as indicators of atmospheric dynamics activities.

We have obtained and compared our results with those obtained by the large telescopes, we have obtained thanks to our site very satisfactory results, Indeed:

For RR lyr:

For the first time the second apparition of Helium (D3) was detected using our Telescope (0.35m) at Oukaimeden Observatory .

For the first time, that the emission, of the line D3 (λ5875.66Å) some helium, during the phase of expansion of the star, is visible on various phases Blazhko including during the minimum of the cycle Blazhko.

Recently in 2022, we find the absence of the influence of the Blazhko effect on the Van Hoof effect linking the metallic lines along FeI λ 4920.509 Å and FeII λ 4923.921 Å in RR Lyr.

Also, we presented the results of a long- term, high-resolution spectroscopic study of the variable star R Sct. We analyzed the features of the optical spectra of this object and found: RSct shows irregular behavior in it slight. variations for much of the time that it was observed. Its average period is close to 142 d, but some- times the irregularities are so strong that it is not possible to define a periodic variation.

KEYWORDS spectroscopy, variables stars, RR lyr, R sct, atmospheric dynamics

IAUS 371

#2271

Atomic Data from the UV to the IR

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Modern ground- and space-based spectrographs have made the acquisition of astronomical spectra possible at unprecedented resolutions across the infrared, visible and ultraviolet spectral regions. These spectra, acquired with great resource investment, highlight a critical need for laboratory atomic data for accurate and reliable interpretation. Poor quality atomic data is often the weakest link in modern astronomical spectral analyses, and at least order-of-magnitude improvements in the accuracy of the atomic data are often required. With the development of telescopes such as the ELT and JWST, the demand for advances in atomic data is only expected to grow in the future.

Accurate atomic data are vital for the reliable identification of complex spectral line structures and form the foundation of spectrum synthesis models and chemical elemental abundance determinations. The development of 3D non-LTE hydrodynamical atmospheric models has greatly improved modelling capability but has placed even greater requirements on the breadth and quality of the underlying atomic data. Large scale stellar abundances, such as those in galactic surveys (e.g. Gaia ESO, WEAVE) also rely on accurate atomic linelists, including spectral line wavelengths and transition probabilities (log gfs). Atomic data for the iron group elements are especially important, because of their large number of electronic transitions and high relative abundances. Recently, there has also been an increased demand for improved data for heavy elements, particularly r-process elements, to understand stellar nucleosynthesis.

This keynote will provide an overview of the atomic data required for the analysis of modern astronomical spectra, update the community about research progress in the field of atomic spectroscopy, and aims to continue the dialogue between astronomers and laboratory spectroscopists to learn about new current and future atomic data needs for astronomy.

KEYWORDS Atomic Data, Wavelengths, Transition Probabilities, Energy Levels, Spectroscopy

IAUS 371
#2484

Accurate new atomic data needed for Galactic Surveys

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For the last 20 years, Galactic Surveys have been revolutionizing our vision of the Universe and broadening our understanding of the vastness of space that surrounds us. Galactic Surveys like APOGEE, Gaia-ESO, GALAH and the currently-under-development 4MOST have taught us a great deal about the chemical composition of stellar atmospheres, the formation and evolution of galaxies and how elements are synthesised in the Universe. However, many questions still remain unanswered and are the current focus of ongoing and future surveys.

Answering each of these questions requires the collection of data, normally in the form of spectra, as most of the information we receive from the universe is electromagnetic radiation. Each question needs the spectra to be measured in different spectral ranges and with different resolving powers. Following the very expensive acquisition of astronomical spectra, another crucial task lies ahead: the analysis of these spectra to extract the priceless information they carry.

Accurate atomic data for different elements (transition probabilities, wavelengths, hyperfine structure constants, Stark widths) allows astronomers to infer from the shapes, widths and shifts of the spectral lines emitted by atoms and ions not only the chemical composition of stellar and exoplanet atmospheres, but also their temperatures, velocities, electron densities and magnetic fields. However, a great quantity of the atomic data needed for spectra interpretation is yet to be obtained.

This talk aims to provide an overview of the current efforts being made by different laboratories around the world to successfully measure high-quality atomic data urgently needed by astronomers to analyse spectra gathered by different Galactic Surveys. Previously successful collaborations between laboratory astrophysics and Galactic Surveys such as Gaia-ESO or APOGEE are the best proof that an understanding of laboratory capabilities is vital for any fruitful collaboration between astronomers and spectroscopists.

KEYWORDS atomic data, emission spectroscopy, transition probabilities, galactic surveys

IAUS 371

#665

New Laboratory Atomic Data for Neutral, Singly and Doubly Ionised Iron Group Elements for Applications in Astrophysics

Milan Ding[1], Christian Clear[1], Florence Concepcion[1], Juliet Pickering[1]

[1]*Physics, Imperial College London, United Kingdom*

We report new laboratory atomic data for the species of astrophysical importance: neutral, singly and doubly ionised iron group elements, measured using high-resolution Fourier transform spectroscopy (FTS). The resolving power of this spectroscopic technique can be up to 2×106 at 200 nm, which enables wavelength measurements accurate to a few parts in 108. We use lists of accurately measured transition wavelengths to improve known atomic energy levels and search for new energy levels. Spectra are also analysed for branching ratios to determine log gfs, and for characterising line broadening effects such as isotope structure and hyperfine structure. Theoretical calculations of such atomic data cannot reach the accuracy required by many astrophysical spectral analyses, examples including: line identification, blend disentanglement, spectral synthesis, and abundance determination (e.g. Bergemann et al. (2010)), etc.

At Imperial College, we have a unique visible-VUV Fourier transform spectrometer sensitive down to 135 nm. In order to produce comprehensive atomic data, our FTS measurements are supplemented at shorter wavelengths by measurements in collaboration with G. Nave using the NIST 10.7 m grating spectrograph and at longer wavelengths by using the NIST IR FT spectrometer. Examples of our recent work on new atomic data include: magnetic hyperfine structure splitting constants of Co II (Ding & Pickering (2020)), transition wavelengths and energy levels of Mn II (Liggins et al. (2021)), and improved Ni II transition wavelengths for quasar absorption spectroscopy (Nave & Clear (2021)). Work is also ongoing for Ni II, Fe III, and lanthanides such as Nd II and Nd III. Order-of-magnitude improvements in accuracy of transition wavelengths and level energies have been possible.
This work is supported by the STFC (UK).

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KEYWORDS atomic data, laboratory, spectroscopy, line identification, line profile, abundances

IAUS 371
#2948

Precision X-ray spectroscopy

Randall Smith[1]

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X-ray astronomy has exquisite promise that has always been limited by a sparsity of photons. Where other bandpasses have telescopes the size of cars to tennis courts, X-rays are closer to dinner plates — and to get high-resolution with a grating meant cutting the flux further. With the upcoming launch of micro calorimeters on XRISM and Athena, along with advances in X-ray gratings, plentiful high-resolution spectra are just over the horizon. I will discuss what we've learned so far about the implications of these new facilities for existing spectral databases, and some of the highest priority needs to extract the maximum of results from upcoming observations. The needs go beyond improvements in wavelengths and flux calculations; real progress will require close collaboration between observers, instrument calibrators, theorists, and lab astrophysicists to understand which features signal new physics versus those that are simply misleading.

KEYWORDS X-ray, spectroscopy, XRISM, Athena, gratings

IAUS 371
#2366

The Fe XVII 3C/3D Oscillator Strength Problem

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The interpretation of line features in X-ray spectra recorded by space observatories depends on the availability of models, which are often based on atomic-structure calculations. These have to be benchmarked by laboratory experiments, and the ubiquitous ions of iron are of highest priority. For decades, astrophysical observations as well as laboratory measurements of the oscillator strength ratio of the resonance line 3C, (2p5)1/23d3/2 (J=1) to 2p6 (J=0), and the intercombination line 3D, (2p5)3/23d3/2 (J=1) to 2p6 (J=0), in Ne-like iron Fe XVII have disagreed significantly with theoretical values. This has raised questions about the reliability of spectral models based on calculated line intensities, and possible origins of the discepancy have been extensively studied in experiments and theory. This was complicated by the fact that the primary excitation mechanism in experiments was electron impact, which introduces a plethora of phenomena that have to be taken into account.

In the experiments presented this was addressed by using an electron beam ion trap (EBIT) to provide targets of trapped Fe XVII ions for ultrabrilliant photon beams from x-ray light sources. By observing resonantly excited fluorescence high-resolution spectra can be recorded. First pioneering experiments of this kind were conducted at the Linac Coherent Light Source (LCLS) free-electron laser, and their results seemed to hint at shortcomings of atomic-structure calculations. However, possible systematic effects in the LCLS measurements were pointed out. These were excluded in recent experiments at the synchrotron facility PETRA III. They were conducted using the novel compact PolarX-EBIT and the high-resolution monochromator of beamline P04, which led to much improved spectral resolving powers and signal-to-noise ratios, uncovering hitherto unaccounted-for contributions to the measured line shapes. When these are taken into account, measured and newest calculated oscillator strength agree, which is underpinned by simultaneous determinations of the natural linewidths of 3C and 3D. This has finally provided a satisfactory resolution to the 3C/3D oscillator strength problem.

KEYWORDS x-ray spectroscopy, electron beam ion trap, Fe XVII, free-electron laser, synchrotron, atomic-structure

IAUS 371
#2877

Modeling X-ray Emission from Charge Exchange Collisions in Astrophysical Spectra

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Interest in astrophysical sources of charge exchange (CX) has grown following the first observation of X-ray emission in comet Huakutake in 1996. Further studies proved that this emission was primarily due to charge exchange collisions between neutrals in the cometary coma and ions from the solar wind. CX has since been observed throughout our solar system such as in the atmospheres of Mars and Jupiter. Additionally, observations from starburst galaxies, supernova remnants, and even the Perseus Cluster have hinted at the possibility of CX. Studies of these regions have thus far been limited by models that do not fully account for the various ionization stages and/or neutral species or collisional velocities present in CX spectra. With high-resolution observations made available by future X-ray missions such as XRISM and Athena, highly reliable CX models are necessary to interpret the contribution of CX in any spectrum. Here, I will briefly review various approaches for modeling charge exchange as well as the laboratory measurements that allow us to test the reliability of these models enabling better interpretation of future observations of CX.

KEYWORDS charge exchange, laboratory astrophysics, atomic theory, X-rays

IAUS 371
#2804

Models of Hazes in (exo)planetary atmospheres - The Importance of Producing and Characterizing Laboratory Analogs of (Exo)Planetary Atmospheric Aerosols

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Cloud and haze particles have been observed in (exo)planetary environments. Dedicated laboratory experiments have been developed to produce analogs of these solid materials under different experimental conditions (molecular precursors, temperature, pressure, energy source…). These experimental studies are key to investigating the physical and chemical processes that drive the formation of solid particles from gas and solid phase molecular precursors in astrophysical and planetary environments. They also allow the characterization of the physical, optical, and chemical properties of these laboratory-generated analogs, hence providing critical information that can be used as input parameters in models for the analysis and interpretation of observational data.

Here, as examples of these laboratory efforts, we will present various studies that combined (1) experiments performed with different facilities to produce analogs of Titan, Pluto and exoplanet atmospheric aerosols from gas phase molecular precursors, and (2) the characterization of these analogs to provide their morphology, composition, and the real and imaginary parts of their refractive indices, n + ik, to the community. We will also present a new effort to develop the NASA Center for Optical Constants to provide this critical data to the scientific community for planetary-relevant ices and organic refractory materials produced from gas and ice irradiation.

KEYWORDS exoplanet, haze aerosol analogs, laboratory astrophysics, atmospheric chemistry, optical constants

IAUS 371

#2908

The Next-Generation Laboratory Experiments on Planetary Materials

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Laboratory experiments have been found to be extremely important in the field of planetary and exoplanetary science. In this talk, I will introduce my envisioned next-generation laboratory research and my previous and current works on achieving these visions. I will include four topics: 1) using material science techniques to study planetary materials, 2) collaborative laboratory research on planetary and exoplanetary haze analogs, 3) the next-generation planetary regolith analog materials, and 4) building a robust laboratory database to better understand various atmospheric and surface processes on Titan and exoplanets. I will also elaborate on how such laboratory work could power next-generation space missions such as the Dragonfly mission to Titan and the James Webb Space Telescope.

KEYWORDS Titan, Exoplanet, Planetary material, material characterization, laboratory research

IAUS 371
#2649

Signatures of r-process elements in kilonova spectra

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Binary neutron star mergers have been expected to synthesize r-process elements and emit radioactively powered radiation, called kilonova. Although r-process nucleosynthesis was confirmed by the observation of GW170817/AT2017gfo, it is not yet clear which elements were synthesized except for strontium. Moreover, while spectroscopically accurate data is needed to decode the spectra, such data is currently limited especially for heavy elements. Toward element identification in kilonova spectra, we systematically investigate the strength of bound-bound transitions for all lines by using the line list from theoretical calculations. We find that not only strontium but also lanthanide elements can show strong transitions and produce absorption lines. The ions which can become strong absorption sources can be explained by atomic properties. We also perform radiative transfer simulations in neutron star merger ejecta by combining theoretically constructed atomic data and experimentally calibrated atomic data. We compare the results to the kilonova spectra associated with GW170817, and discuss prospects to identify r-process elements synthesized in the ejecta.

KEYWORDS kilonova, r-process, atomic data, neutron star

IAUS 371
#1511

Kilonovae and the cosmic origin of r-process elements: atomic structure and processes of gold

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The cosmic origin of elements beyond iron in the periodic table is a long-standing puzzle. As such, one of the main astrophysical highlights of the last decade is without doubt the indication of rapid neutron capture (r-process) nucleosynthesis of heavy elements in the kilonova (KN) ejecta following the neutron-star (NS) merger gravitational-wave event in 2017. This event is the first-ever observational argument that kilonovae are the main sites for the production of neutron-rich elements in the universe, but the extent of the contribution of these elements is still under debate. A careful analysis of KNe spectra based on reliable atomic parameters is crucial, not only to allow for direct element identifications in KN spectra, but also to determine fundamental parameters of the ejecta itself, and ultimately of the progenitor binary NS system. However, much of the atomic structure and radiative properties of the neutron-capture elements are unknown or poorly constrained - especially in the infrared spectral region, which is particularly prominent in KN spectra.

A good representation of the complexity of many heavy elements is gold. Although the neutral atom is a nominal one-electron system with a 5d(10) 6s ground configuration, representing the complete energy spectrum and transition properties comes with a range of theoretical challenges. In this contribution, we present new theoretical and experimental investigations of the atomic structure and radiative properties of gold, with a particular focus on the near-infrared spectral region. The calculations are carried out with the relativistic atomic structure code GRASP2018. Furthermore, we use the case of gold as an example to investigate semi-empirical techniques via rescalings of matrix elements for improved accuracy of the calculated transition properties and KN expansion opacities. The development of such methods will be crucial for cases of even more complex neutron-capture elements.

KEYWORDS atomic data, atomic processes, stars: neutron, opacity, supernovae: individual: AT2017gfo, neutron star mergers, line: identification

IAUS 371

#2689

The Synergy Between Laboratory Spectroscopy and Observational Astronomy in the Far-IR

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The recent deployment of several far-IR observatories has led to an explosion of molecular information about our universe. The Herschel Observatory, the Stratospheric Observatory for Infrared Astronomy (SOFIA) and the Atacama Large Millimeter/submillimeter Array (ALMA) have revealed the fundamental roles that molecules play in the varying physical environments of the interstellar medium and circumstellar medium. While this wealth of new information has led to rapid developments in our understanding of molecular astrophysics, there are many aspects of this chemistry that remain poorly understood. There are numerous unassigned molecular lines in the archival spectra from these observatories. There are a large number of molecules for which high frequency spectra, spectra of excited vibrational states, and spectra of isotopoloques remain incomplete. Astrochemical models predict several key radicals and ions that drive the chemistry, and hence the physics, of these regions, and yet no spectra have been obtained for these unstable species. Laboratory studies of the rotational spectra of all of these molecules are required to guide observations and to increase the science return from archival data. In this talk I will present the astrophysical motivation for rotational spectroscopy of molecules. I will present the state-of-the art in experimental techniques for labotoratory rotational spectroscopy. I will discuss the limitations of these approaches and where gaps in our knowledge remain. I will then discuss ongoing work to address these challenges.

KEYWORDS spectroscopy, laboratory astrophysics, molecules

IAUS 371
#2957

Molecular Spectroscopy with optical frequency combs

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The advent of optical frequency combs has lead to a revolution of molecular spectroscopy. We have applied them to precision mid-infrared spectroscopy and broadband near-infrared dual-comb spectroscopy.

We have developed a 3.3-µm sub-Doppler resolution spectrometer using a difference frequency generation (DFG) source of the 1.06- and 1.55-µm waves, an enhanced-cavity absorption cell, and an Er-doped fiber comb spectrally broadened to cover the 1.06- and 1.55-µm waves. The spectral linewidth of the observed Lamb dips is about 300 kHz at an optical frequency of 90 THz, and the transition frequency is determined with a typical uncertainty of 10 kHz. The comb-assisted spectrometer has allowed us to determine precise transition frequencies of the ν3 band [1,2] and the ν3 - 2ν3 A1 band [3] of methane, the fundamental band of hydrogen chloride [4]. It has also been applied to study of Stark effects of methane [5] and search for inversion splitting of phosphine [6].

Dual-comb spectroscopy has advantages over FTIR in a precise frequency scale and a fast data acquisition. We have developed a ultra-broadband dual-comb spectrometer. The emission spectra of two combs are broadened from1.0 to 1.9 µm using highly nonlinear fibers. To avoid the aliasing, which reduces the spectral coverage, the difference in the repetition rates between the two combs must be set smaller than 10 Hz. To do so, an EO modulator is inserted in the laser cavity for fast servo control. Then we have observed the ultrabroad spectrum, in which overtone bands of water, methane, and acetylene are observed [7].

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KEYWORDS comb, dual-comb, methane, infrared, spectroscopy, precision spectroscopy

IAUS 371
#2799

Laboratory Challenges for Solar System Science

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Advances in understanding the Solar System and the processes occuring throughout are strongly connected to laboratory and theoretical studies These studies (experimental and theoretical) are crucial to interpret observations and mission data, and are key incubators for new mission concepts as well as instrument development and calibration. Additionally, such experiements can enhance our understanding of the origin of life, and in the search for habitability or fossils of former life. Almost all aspects of Solar System exploration and discovery are in need of new laboratory and theoretical investigations to promote our understanding of these extreme environments and the processes occuring throughout. Key targets and environments of interest include planetary & satellites atmospheres, surfaces, and interiors, primitive bodies such as asteroids, meteorites, comets, and trans-Neptunian objects. The broader application is perfectly suited for exoplanet studies in the next generation of transit spectroscopy and imaging as well as new studies of star and planet formation. Advances in observational facilities including the James Webb Space Telescope, the Atacama Large Millimeter Array, and numerous planetary science missions (e.g. Europa Clipper, OSIRIS-REx, DAVINCI, or a future outer planets mission) are all providing incredible new scientific discoveries and data that are in dire need for detailed analysis with theoretical and laboratory simulations, spectroscopic parameters/constants, varied physical conditions, etc. Generating targeted experimental and theoretical laboratory data that are relevant for a better understanding of the physical, chemical, and possibly biological processes occurring in these environments is crucial. This presentation will present some fundamental needs for the analysis and interpretation of Solar System data and some new experimental approaches to help address them.

KEYWORDS Laboratory Astrophysics, Solar System, James Webb Space Telescope, planetary science

IAUS 371

#2499

Heavy element opacity for multi-messenger observations of neutron star mergers

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Binary neutron star mergers are the primary targets for gravitational wave observations. In addition, they give rise to electromagnetic emission called kilonova, thermal emission powered by radioactive decays of newly synthesized r-process nuclei. Observational properties of kilonova are largely affected by bound-bound opacities of heavy elements. Thus, it is important to understand atomic properties of heavy elements to link the observed signals with nucleosynthesis of neutron star mergers. In this talk, I will review the current understanding of opacities for kilonova. Then, I discuss prospects for element identification in kilonova spectra by focusing on the atomic data of heavy elements.

KEYWORDS opacity

IAUS 371
#2988

VUV Spectroscopy for Photoprocessing of Astrophysical Ices

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[3]*Physics, NAtional Central University, Taiwan*

VUV emission spectrum of microwave-discharged hydrogen-flow lamp (MDHL) generated in the laboratory has an analogous profile analogous the secondary VUV field induced by cosmic rays as they excite atomic and molecular hydrogen in cold dense cloud interiors. The operation configuration of MDHL manipulates the photon energy distribution, and therefore induces changes in the photochemistry and photodesorption of astrophysical ices. The first step of photoprocessing is photon absorption in the ice, which is related to the photon energy distribution of the MDHL emission and absorption cross section of the ice at this range. The Ly-α (121.6 nm) photons were thought to play a vital role in photoprocessing of astrophysical ices, however, it is transparent to CO ice. In this talk we will present the photon energy distribution effect on photodestruction and photodesorption of few astrophysical ices, especially the VUV destruction cross section is also ice thickness dependent, while in many studies only the incident photon flux is considered.

KEYWORDS VUV Spectroscopy, Photoprocess, Interstellar Ice, ISM, Photodesorption

IAUS 371

#2714

Branching Ratios and Atomic Transition Probabilities of Fe II in the Vacuum Ultraviolet Region

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The spectrum of singly ionized iron (Fe II) is a dominant component of many astrophysical spectra and accurate models of complex astrophysical spectra require comprehensive atomic data for Fe II transitions. While much laboratory work has been dedicated to providing atomic data for the spectrum of Fe II, the vacuum ultraviolet region (VUV) is experimentally difficult to work in and therefore, there is a lack of comprehensive data in this region. In particular, atomic transition probabilities in the VUV are inadequately reported on in current atomic spectra databases. Only two previous publications report on measurements of Fe II transition probabilities with transitions in the VUV. I will present our recent measurements of the relative intensities of singly ionized iron (Fe II) emission lines from a high current hollow-cathode light source in the vacuum ultraviolet region (VUV). These relative intensities were measured using high resolution Fourier transform spectrometers at The National Institute of Standards and Technology and were used to determine Fe II branching fractions. The measured branching fractions were combined with calculated level lifetimes to derive transition probabilities and oscillator strengths data for Fe II in the VUV. The work I present here more than doubles the available transition probability data in the VUV.

KEYWORDS Laboratory Astrophysics, Atomic Spectroscopy, Atomic Physics, Ultraviolet Astronomy, Atomic Data

IAUS 371

#2945

High Resolution Molecular Spectroscopy in the CAS Laboratories

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Molecules are unique tracers of the different phases in the formation of stars and planetary systems, and hence provide the chemical link to understand the emergence of life on Earth. Laboratory spectroscopy is a mandatory step in order to observe molecules in space. The work of numerous groups around the world has been meticulously collected in a few database to facilitate the job of observers and to bridge the two communities (spectroscopists and astronomers). Despite the huge amount of spectroscopy done in the past decades, a lot of work is still needed.

The Center for Astrochemical Studies (CAS) at the Max Planck Institute for Extraterrestrial Physics in Garching brings together observers, theoreticians, chemists and molecular astrophysicists with the ultimate goal of unveiling our astrochemical origins. In my talk, I will briefly introduce our laboratory facilities for high-resolution spectroscopy in the gas-phase of both stable molecules and elusive species like radicals and ions, highlight our recent results, and give an outlook to our future plans. In particular, I will present our recent work on the millimetre and sub-millimetre spectroscopy of doubly deuterated acetaldehyde (CHD2CHO).

Complex organic molecules like acetaldehyde (defined as molecules with more than 5 atoms, containing Carbon, Oxygen and Hydrogen) are ubiquitous in star forming regions. They are very abundant around protostars, in the so-called “hot corinos” in low-mass forming regions, and towards “hot-cores” in high-mass forming regions (Taquet et al., 2015 and Bonfand et al., 2019). Very recently we started observing complex organic molecules also towards starless and pre-stellar cores (Bizzocchi et al. 2014, Jimenez-Serra et al. 2016, Scibelli et al. 2021). Isotopic fractionation, and in particular deuteration, is a crucial process to follow the evolution of material in the process of star- and planetary system formation. With our work on the spectroscopy of doubly deuterated acetaldehyde, we provide an accurate catalogue for this molecules up to 500 GHz, allowing for the first time to search for it in the ISM (Ferrer Asensio et al., in prep.).

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KEYWORDS Astrochemistry, Laboratory Spectroscopy, Deuterated molecules, Complex Organic Molecules

e-Posters

IAUS 371

#2979

Branching fractions and transition probabilities in the spectrum of singly-ionized chromium (Cr II)

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Experimental transition probabilities of iron-group elements in the ultraviolet and vacuum ultraviolet are of vital importance for the interpretation of astrophysical spectra. However, their measurement poses several problems, including the difficulties of measuring lifetimes for the high-excitation levels giving lines in the vacuum ultraviolet, the challenges of measuring branching fractions over a wide wavelength range, and inaccurate results from mis-identifications of spectral lines and from line blending in complex spectra. We shall illustrate these problems and their solutions with measurements of transition probabilities in Cr II, using critically-evaluated theoretical lifetimes combined with branching ratios of low-current hollow cathode lamps, high-current hollow cathode lamps, and Penning discharge sources using Fourier transform spectroscopy.

KEYWORDS Atomic Data, Transition probabilities, Branching fractions, ultraviolet

Elemental abundances in the Sagittarius dwarf galaxy: Evidence for sub-Chandrasekhar mass type Ia supernovae, s-process enhancement

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Our Local Group dwarf galaxies provide a window to understand the chemical evolution of galaxies other than our Milky Way, and to constrain the astrophysical sites of nucleosynthesis.

Here, we present a detailed chemical abundance analysis of stars in the Sagittarius dwarf galaxy (Sgr), based on high-resolution (R ~ 48,000), high S/N spectra obtained using the MIKE spectrograph on the Magellan Clay telescope. We derived abundance estimates of the alpha, iron peak, and neutron-capture elements (including Y, La, Ce, and Eu). Our results are in good general agreement with previous studies of Sgr. In particular, we reconcile the [α/Fe] deficiencies and normal [Eu/Fe] trends seen relative to the Milky Way. We find a deficiency of [Ni/Fe] ratios in all stars, with the largest deficiency shown by the most metal-rich star in our sample. Similar [Ni/Fe] deficiencies have previously been found in other dwarf galaxies, attributed to enrichment by sub-Chandrasekhar mass type Ia supernovae. In addition, we obtained high [La/Y] enhancements suggesting that metal-poor, low-mass AGBs dominated the s-process nucleosynthesis in Sgr.

KEYWORDS Stellar spectroscopy, Elemental abundances, Nucleosynthesis, Galactic Chemical Evolution, Dwarf Galaxies

IAUS 371

#1333

Separating Orbital Radial Velocities and Spectral Shape Variation with a new type of periodogram

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We present a new type of periodograms that are effective in distinguishing Doppler shift from spectral shape variability. These periodograms are based on the concept of partial distance correlation. They separate the periodic radial velocity modulation induced by orbital motion from that induced by stellar activity or any other type of spectral shape variability. These novel tools can be used to explore large spectroscopic databases in search of targets in which spectral shape variations obscure the orbital motion; such systems can be active planet-hosting stars or binary systems with an intrinsically variable component such as a Cepheid.

KEYWORDS periodicity, stellar activity, Doppler shift, radial velocity

IAUS 371
#1517

New laboratory atomic data for doubly-ionised iron for applications in astrophysics

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There is an acute need for accurate atomic data for doubly-ionised iron (Fe III) as its spectral lines are present and numerous in many astrophysical sources, due to its high relative abundance and complex spectrum.

We report the results of new accurate laboratory atomic data for Fe III. The emission spectrum of Fe III has been recorded using the high-resolution VUV Fourier transform (FT) spectrometer at Imperial College London, UK, which has a resolving power of ~2 million at 200 nm, producing the most accurate Fe III linelist to date. Accurate wavenumbers have been measured using FT spectroscopy in the UV-VUV (152.7 nm to 295.6 nm), with the strongest lines having uncertainties between 0.000027 nm and 0.00012 nm. At lower wavelengths (< 152 nm), beyond the lower wavelength limit of FT spectrocopy, data is supplemented with grating spectra from the 10.7 m normal incidence vacuum spectrograph at the National Institute of Standards and Technology in Gaithersburg, Maryland, USA.

An extensive term analysis of the lower-lying levels of Fe III has resulted in new Fe III atomic data including the revision of over 300 previously published atomic energy level values. New accurate Ritz wavenumbers for ~1600 identified spectral lines in the UV-VUV are also reported, which are at least an order of magnitude improvement in accuracy over previous publications. The accurate Fe III data presented here have applications in many astronomical fields including as wavelength standards, for the calibration of VUV spectra of hot stars, and for the identification and analysis of Fe III spectral lines in astrophysical objects.

Newly calculated parity-forbidden Fe III Ritz wavelengths for over 400 transitions between the lowest-lying configurations ($3d^6$ and $3d^5$(ML)4s) are also reported to aid astronomers further in the analysis of spectra from dilute astrophysical plasmas.

This work is funded by the STFC UK.

KEYWORDS iron, atomic data, laboratory, high resolution, spectroscopy, wavelengths, line identification

IAUS 371
#1450

Analysis of emission line spectra of active galaxies and fine classification for activity types

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During the accomplishment of several projects on multiwavelength search and studies of active galaxies, we have carried out fine spectral classification using SDSS spectroscopy for several large samples of active galaxies, including those revealed from optical identification and studies of ROSAT X-ray sources (HRC/BHRC), extragalactic sample of Combined IRAS PSC/FSC Catalogue, cross-correlations of NVSS and FIRST radio catalogues, etc., as well as Markarian galaxies and some other samples. More than 10,000 SDSS spectra have been analyzed and classified for activity types. This gives us a big number of objects to aim at the homogeneity in our classifications. A fine classification scheme was developed, where QSOs have subtypes like Seyferts (Q1.0, Q1.2, Q1.5, etc.), Narrow Line QSOs are introduced (NLQ, also with subtypes: NLQ1.0, NLQ1.2, NLQ1.5, etc.), subclasses for Narrow Line Seyfert 1s (NLS1.0, NLS1.2, NLS1.5, etc.) are used and Composite spectrum objects have their subtypes (HII/LINER, HII/Sy, LINER/Sy and HII/LINER/Sy, also with subtypes). This classification scheme much better describes all fine details in the optical spectra and allows further study of active galaxies by the subtypes for better understanding the Unified model and the physical properties of AGN and Starbursts.

KEYWORDS Spectroscopy, Active Galaxies, Starburst Galaxies, AGN, QSO, Seyfert, LINER

e-Talks

IAUS 371

#2982

Physical parameters and magnetic activity of M stars based on LAMOST spectral survey and FAST telescope

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Low mass M stars are the most common type of stars in the Milky way. The astronomical big data enable us to more comprehensively grasp and understand the physical parameters and magnetic activity properties of M stars. We used the Low and medium-resolution spectroscopic data from Large Sky Area Multi-Object Fiber Spectroscopic Telescope (LAMOST) to explore chromospheric statistical properties and chromospheric active variations of H alpha line in the short and long time scales. We revised the relationship between the active fraction and M spectral subtype, which shows that the fraction increase from M0 to M3, and possible decline from M4 to later. By combing the distances from Gaia, we also found the active fraction decrease rapidly in the height region from 0 to 400 pc, and remain stable from 400 to 1000 pc. Using the LAMOST medium-resolution spectra, we studied the chromopsheric activity variation of H alpha in short time scales of 20 minutes and detected many chromospheric flare events. Finally, we will introduce the scientific projects of detecting radio emission from nearby M stars using the Five-hundred-meter Aperture Spherical radio Telescope (FAST).

KEYWORDS Chromospheric activity, M stars, LAMOST, Magnetic activity, flare

IAUS 372
The Era of Multi-Messenger Solar Physics

Invited & Contributed Talks

IAUS 372

#2360

Parker Solar Probe in the Multi-Spacecraft Era

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Parker Solar Probe (PSP) has provided observations at unprecedentedly close radial distances to the Sun, allowing for the first observations of sub-Alfvénic solar wind and unique observations of the solar corona from the Alfvén surface by WISPR. While these unique vantage points alone have enabled robust explorations of the fundamental nature and evolution of the corona and young solar wind, the combination of PSP with other current and historical datasets allow for the most comprehensive and significant advancements to our understanding of the heliosphere. In this presentation, we highlight some of the scientific contributions made by combining PSP observations with those of other space- and ground-based observatories, as well as the current challenges that exist for utilizing this multi-observatory approach. We also highlight efforts by the PSP Project Science team and the Whole Heliosphere & Planetary Interactions (WHPI) initiative for coordinated multi-observatory campaigns centered around PSP parahelia as we move into the ascending phase of this solar cycle.

Keywords Parker Solar Probe, Solar Wind, Energetic Particles, Corona

IAUS 372
#2620

Recent Results of Solar Microwave Imaging Spectroscopy

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Microwave emission serves as a powerful tool for diagnosing the dynamic coronal magnetic field, thermal structure of the solar atmosphere, and magnetic energy release and particle acceleration processes in solar transient events such as solar flares, coronal mass ejections, and jets. In the past decade, we have enjoyed a major transition in solar microwave observing ¬– it has evolved from total-power dynamic spectroscopy or imaging at a few discrete frequencies to true broadband imaging spectroscopy. Although still in their early stages, these spatially, temporally, and spectrally resolved data have already demonstrated the unique power of microwave imaging spectroscopy. In this talk, I will highlight recent results based on this new technique, using examples from facilities including EOVSA, VLA, MUSER, and SRH.

KEYWORDS Solar radio emission (1522), Solar radio telescopes (1523), Solar atmosphere (1477), Solar corona (1483), Solar coronal mass ejections (310), Solar flares (1496)

IAUS 372
#716

The Aditya-L1 Mission of the Indian Space Research Organization

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The Aditya-L1 is the first observatory, scheduled to be launched in late 2022, of the Indian Space Research Organization (ISRO) in space dedicated to solar observations. The spacecraft will carry seven payloads providing uninterrupted observations of the Sun using remote sensing and in-situ measurements from the first Lagrangian point. There are four remote sensing instruments: a coronagraph, a full-disk near-ultraviolet (NUV) imager, and full-sun integrated soft X-ray and hard X-ray spectrometers. In addition, there are three instruments, including a magnetometer, to study the solar wind and interplanetary magnetic field variations during energetic events. For the first time, the Aditya-L1 mission aims to provide the coronal magnetic field measurements from space and spatially resolved solar spectral irradiance in NUV, which is central to the Sun-climate relations. This talk will highlight some of the salient features of the mission and the crucial roles it will play in enhancing our knowledge in the science of the solar atmosphere and heliosphere.

KEYWORDS Solar Atmosphere, Sun Climate, Instrumentation

IAUS 372
#709

The early science phase of Solar Orbiter

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The Solar Orbiter mission of ESA and NASA was launched in February 2020 and is an excellent example of multi-messenger solar physics. Of the 10 science instruments on board, four are in-situ instruments measuring particles and fields at the location of the spacecraft, while six are remote-sensing instruments detecting photons from the Sun or from the Heliosphere. Whereas Solar Orbiter was in its cruise phase during most of 2020 and 2021 when only the in-situ instruments were taking regular observations, it entered its first science orbit after an Earth flyby in November 2021. In March and Early April 2022 Solar Orbiter will pass through its first science perihelion at a distance of 0.33AU to the Sun. During this period, the first set of remote-sensing windows of the mission are scheduled, when the remote sensing instruments will take their first images, spectra and magnetograms of the Sun from up close. After a brief introduction to the mission, the first results, as far as they are available, from the cruise phase and from the first perihelion passage will be presented.

KEYWORDS Solar Orbiter, multi-messenger solar physics

IAUS 372
#1250

The Daniel K. Inouye Solar Telescope: status update and first results

Thomas Rimmele[1]

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The National Science Foundation's 4m Daniel K. Inouye Solar Telescope (DKIST) on Haleakala, Maui is now the largest solar telescope in the world. DKIST's superb resolution and polarimetric sensitivity will enable astronomers to unravel many of the mysteries the Sun presents, including the origin of solar magnetism, the mechanisms of coronal heating and drivers of flares and coronal mass ejections. DKIST's instruments provide highly sensitive measurements of solar magnetic fields, including the illusive magnetic field of the faint solar corona. DKIST has started its operations commissioning phase (OCP), during which science observations based on community proposals are being implemented in service-mode and on a shared-risk basis. We provide an overview of the facility and its unique capabilities, discuss progress with the OCP and present first data and early results.The National Science Foundation's 4m Daniel K. Inouye Solar Telescope (DKIST) on Haleakala, Maui is now the largest solar telescope in the world. DKIST's superb resolution and polarimetric sensitivity will enable astronomers to unravel many of the mysteries the Sun presents, including the origin of solar magnetism, the mechanisms of coronal heating and drivers of flares and coronal mass ejections. DKIST's instruments provide highly sensitive measurements of solar magnetic fields, including the illusive magnetic field of the faint solar corona. DKIST has started its operations commissioning phase (OCP), during which science observations based on community proposals are being implemented in service-mode and on a shared-risk basis. We provide an overview of the facility and its unique capabilities, discuss progress with the OCP and present first data and early results.

KEYWORDS Sun, magnetic fields, corona, stellar atmospheres

IAUS 372
#944

Generation of the solar magnetic field

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The solar magnetic field is thought to be generated by the turbulent motion in the solar interior and the surface. The turbulent and chaotic motion in the convection zone leads to several interesting coherent features such as the 11-year activity cycle and butterfly diagram. Due to the difficulties of the numerical approach and the observation for the solar interior, the generation mechanism of the magnetic field is not fully understood, especially for the 11-year cycle. The recent development of the supercomputer and numerical technique enables us to carry out large-scale calculations, which improve our understanding of the sun. At the same time, local helioseismology is significantly improved in the last decade to evaluate the turbulence and the large-scale flow. The numerical simulation and the observation still have important discrepancies that hinder our understanding of solar magnetic generation. The presenter summarizes the recent improvement of numerical and observational studies for the solar interior in the talk.

KEYWORDS dynamo, convection, rotation, interior

IAUS 372
#1196

Powering solar-type stars magnetism: how are magnetic cycles established and driven?

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We present an extensive study on the dynamo origin of the solar-type star's magnetism, based on a series of 35 3D MHD numerical simulations.

We assess how the combination of rotation and convection via the Rossby number influences the type of magnetism established (short or long cycles, statistically steady activity) and their expected differential rotation (solar-like, anti-solar, cylindrical or almost solid).

This large survey allows us to explain why the Sun possesses a long decadal cycle and a conical differential rotation.

We further assess the amount of energy needed to maintain such angular velocity profiles and magnetic activity. We find that between 0.1 and 3% of the stellar luminosity can be converted into magnetic energy, giving plenty of energy for surface eruptive events to occur. We also compute the magnetic energy spectra and show that the dipole and quadrupole magnetic fields do not collapse in amplitude when the rotation regime becomes anti-solar in agreement with spectropolarimetric observations, and as such cannot simply explain a break of gyrochronology for large Rossby number.

Finally, we discuss various scaling laws that this study allows to derive and that could be tested with dedicated observations, completing the current observational database. In particular, 2 regimes at low and high Rossby number seems particularly interesting to further quantity and model.

KEYWORDS solar dynamo, solar-stellar connection, stellar activity, MHD, numerical simulation, gyrochronology

IAUS 372

#1201

Solar cyclic activity reconstruction now extends to cover the last millennium

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The famous 11-year (Schwabe) solar cycle is the dominant pattern of solar magnetic activity reflecting the oscillatory dynamo mechanism in the Sun. Solar cycles have been directly observed since 1700 in sunspot numbers. While solar variability is known over 12 millennia using indirect proxy data, individual solar cycles and their continuity were not resolved before 1610 CE. Here we reconstruct individual solar cycles for the last millennium using the high-precision 14C data and state-of-the-art models. Cyclic solar activity is reconstructed for the period 971–1900 CE with 85 individual cycles, along with its uncertainties. This more than doubles the number of solar cycles known from direct solar observations. The reconstructed cycles are consistent with sunspot data after 1750 CE. Statistical Waldmeier realtion between the solar cycle parameters has been tested and confirmed with the longer dataset. Thus, solar cycles are reconstructed, for the first time, for about 1000 years, in the form of annual (pseudo) sunspot numbers with the full assessment of all known uncertainties.

KEYWORDS Solar activity, Sunspots, Solar cycles, Cosmogenic isotopes

IAUS 372
#1548

Tracking active regions from the near-Earth to the solar far side by combining SDO/HMI and SO/PHI data

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The study of the evolution of active regions has been limited in time, both by solar rotation and by the inability to observe the far side solar photosphere from Earth. The Polarimetric and Helioseismic Imager (PHI) on board the Solar Orbiter (SO) satellite provides the unique opportunity to see the solar far side in intensity and magnetic field. Combining SO/PHI far-side observations from opposition with near-Earth observations of the Helioseismic and Magnetic Imager (HMI) on board the Solar Dynamics Observatory (SDO) allows the tracking of active regions almost uninterrupted for a full solar rotation or even longer. We make use of data acquired with the full disc telescope of SO/PHI during Solar Orbiter's first opposition during cruise phase in February 2021. Four active regions are tracked from the near-Earth side in HMI intensity maps and magnetograms, to the far side where they become visible in the field of view of SO/PHI. Three of the active regions are in a decaying stage and do no longer show signals in intensity when reaching the field of view of SO/PHI. One of the active regions, emerging when visible on the near-Earth side, develops pores on the far side and rotates back into the field of view from Earth where the decaying process is observed. We will present the longest almost uninterrupted study of the evolution of the magnetic field of active regions, achieved so far. This shows the uniqueness of combining Solar Orbiter and near-Earth side observations for continuously study the evolution of long-lasting active regions.

KEYWORDS photosphere, active regions, magnetic fields, solar far side

IAUS 372
#1515

Origin of extreme solar eruptive activity from the active region NOAA 12673 and the largest flare of solar cycle 24

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During 2017, when the Sun was moving toward the minimum phase of solar cycle 24, an exceptionally eruptive active region (AR) NOAA 12673 emerged on the Sun during August 28-September 10. During the highest activity level, the AR turned into a βγδ-type sunspot region, which manifests most complex structure of magnetic fields from the photosphere to the coronal heights. The AR 12673 produced four X-class and 27 M-class flares, along with numerous C-class flares, making it one of the most powerful ARs of solar cycle 24. Notably, it produced the largest flare of solar cycle 24, namely, the X9.3 event on 2017 September 6. In this work, we provide the results of our comprehensive analysis involving multi-wavelength imaging and coronal magnetic field modeling to understand the evolution and eruptivity from AR 12673. We especially focus on the morphological, spectral, and kinematical evolution of the two X-class flares on 2017 September 6. We quantitatively assess the link between the large- and small-scale changes in the magnetic fields of the active region with the occurrence of subsequent outbursts during the X-class flares. We also provide a detailed investigation of various aspects of magnetic flux rope structures along with the topology of coronal magnetic fields in 3-dimension. The study also reports a very interesting case of the anomalous expansion of the CME at the source region on 2017 September 7 which are found to be intimately connected with the non-radial eruption of a double-decker flux rope from a mini-sigmoid region of NOAA 12673. Our study reveals that the combination of ideal 'torus' instability and resistive processes is responsible for the onset of eruptions from the source region which eventually resulted into the CMEs.

KEYWORDS Solar Flares, Coronal Mass Ejections, Magnetic flux ropes

IAUS 372

#339

Solar flare-CME association

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With the aim of understanding how the magnetic properties of active regions (ARs) control the eruptive character of solar flares, we analyze 719 flares of Geostationary Operational Environmental Satellite (GOES) class $\geq$C5.0 during 2010$-$2019. We carry out the first statistical study that investigates the flare-coronal mass ejections (CMEs) association rate as function of the flare intensity and the AR characteristics that produces the flare, in terms of its total unsigned magnetic flux ($\Phi$$_{AR}$). Our results show that the slope of the flare-CME association rate with flare intensity reveals a steep monotonic decrease with $\Phi$$_{AR}$. This means that flares of the same GOES class but originating from an AR of larger $\Phi$$_{AR}$, are much more likely confined. Based on an AR flux as high as 1.0$\times$$10^{24}$ Mx for solar-type stars, we estimate that the CME association rate in X100-class ``superflares" is no more than 50\%. Our results imply that $\Phi$$_{AR}$ is a decisive quantity describing the eruptive character of a flare, as it provides a global parameter relating to the strength of the background field confinement. By considering both the constraining effect of background magnetic fields and the magnetic non-potentiality of ARs, we propose a new parameter α/$\Phi$$_\mathrm{AR}$ to measure the probability for a large flare to be associated with a CME. We find that in about 90\% of eruptive flares, $\alpha$$_\mathrm{FPIL}$/$\Phi$$_\mathrm{AR}$ and $\alpha$$_\mathrm{HFED}$/$\Phi$$_\mathrm{AR}$ are beyond critical values (2.2$\times$$10^{-24}$ and 3.2$\times$$10^{-24}$ Mm^{-1} Mx^{-1}), whereas they are less than critical values in $\sim$ 80\% of confined flares. This indicates that the new parameter α/$\Phi$$_\mathrm{AR}$ is well able to distinguish eruptive flares from confined flares. Our investigation suggests that the relative measure of magnetic nonpotentiality within the AR core over the restriction of the background field largely controls the capability of ARs to produce eruptive flares.

KEYWORDS Solar flares, Coronal mass ejections (CMEs), Solar activity

IAUS 372

#2283

Solar Observations with ALMA: a New Frontier

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Solar observations with Atacama Large Millimeter-Submillimeter Array (ALMA) became available to the community in late-2016. For the first time, high angular resolution (sub-arcsec) and high-time-resolution (1 s) observations of the Sun became possible at millimeter wavelengths, providing observations of the solar chromosphere that are uniquely complementary to those in O/IR and UV wavelengths. This talk will briefly review current ALMA capabilities, present selected results of ALMA observations of the Sun, discuss current and future synergies with other instruments such as IRIS and DKIST, and describe future capabilities. Access to resources to learn more about ALMA and to propose for observing time will be provided.

KEYWORDS Solar instruments, Millimeter astronomy, Submillimeter astronomy, Solar chromosphere, Solar active regions, Solar spicules

IAUS 372
#956

MHD waves in chromospheric fibrillar structures as observed with ALMA

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Waves and oscillations have been shown as a prime means of transporting energy through the solar atmosphere, thus, contributing to the high temperature of the upper layers. In particular, magnetohydrodynamic (MHD) waves are observed in a number of structures in the solar chromosphere, often with observations in the near-ultraviolet (UV) to infrared wavelength range. In this talk, I will present our recent work on identification of MHD wave modes in a number of fibrillar structures using high-temporal resolution (i.e., 2~s cadence) observations with the Atacama Large Millimeter/submillimeter Array (ALMA) in Band 6 (centred at 1.2~mm). Such oscillations are further compared with those identified in observations at near- and far-UV wavelengths (i.e., Mg ii k and C ii spectral lines) with the Interface Region Imaging Spectrograph (IRIS) space telescope.

KEYWORDS Sun, chromosphere, oscillations, magnetic fields

IAUS 372

#389

Estimating physical parameters of quiet Sun corona using low-frequency spectro-polarimetric radio images

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With improved observations, we are discovering that the so-called "quiet corona" is not so quiet at all. The electron density, temperature, and magnetic field strengths are lower in the quiet Sun regions, as compared to the active regions. As this medium provides the background environment in which all of the coronal dynamics and eruptive phenomena take place, it is important to estimate the plasma parameters of the ambient quiet corona. At higher coronal heights (more than 1.3 solar radii), the emissivity of the corona becomes too low to be measurable in visible, EUV, and X-ray bands. It is hence hard to measure the physical parameters of the corona at higher coronal heights using these observing bands. Low-frequency radio observations are particularly suitable for gathering this information. Using new-generation radio interferometers, like the Murchison Widefield Array (MWA), it is now possible to make high dynamic range spectro-polarimetric solar images of the Sun. Our recently developed robust polarization calibration and imaging pipeline delivers imaging dynamic ranges spanning a few hundred to 105 with very low residual instrumental polarization (less than 0.05%). These images can provide the means to estimate the coronal electron density and temperatures at higher coronal heights routinely. Also, though thermal emission is unpolarized, on passing through the inhomogeneous magnetized coronal plasma it picks up a weak circular polarization (less than 1%) due to the birefringent nature of this medium. It is possible, in principle, to measure the large-scale quiet Sun coronal magnetic field by measuring this weak circular polarization. We present the first-ever detection of circular polarization from quiet Sun thermal emission and use it to estimate the large-scale ambient coronal magnetic field. This forms a convincing demonstration that high fidelity spectro-polarimetric imaging at low radio frequencies provides a novel method for estimating the physical parameters of the corona.

KEYWORDS Sun, Radio Sun, Quiet Sun magnetic field, Square Kilometer Array, Polarization imaging, Low-frequency radio Sun, Solar corona

IAUS 372

#2444

Forward Modeling of Solar Coronal Magnetic-field Measurements Based on a Magnetic-field-induced Transition in Fe X

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It was recently proposed that the intensity ratios of several extreme ultraviolet spectral lines from Fe X ions can be used to measure the solar coronal magnetic field based on magnetic-field-induced transition (MIT) theory. To verify the suitability of this method, we performed forward modeling with a three-dimensional radiation magnetohydrodynamic model of a solar active region. Intensities of several spectral lines from Fe X were synthesized from the model. Based on MIT theory, the intensity ratios of the MIT line Fe X 257 Å to several other Fe X lines were used to derive magnetic-field strengths, which were then compared with the field strengths in the model. We also developed a new method to simultaneously estimate the coronal density and temperature from the Fe X 174/175 and 184/345 Å line ratios. Using these estimates, we demonstrated that the MIT technique can provide reasonably accurate measurements of the coronal magnetic field in both on-disk and off-limb solar observations. Our investigation suggests that a spectrometer that can simultaneously observe the Fe X 174, 175, 184, 257, and 345 Å lines and allow an accurate radiometric calibration for these lines is highly desired to achieve reliable measurements of the coronal magnetic field. We have also evaluated the impact of the uncertainty in the Fe X 3p4 3d 4D5/2 and 4D7/2 energy difference on the magnetic-field measurements.

KEYWORDS Magnetohydrodynamics, Solar magnetic fields, Solar corona

IAUS 372

#1191

How has the solar wind evolved to become what it is today?

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The Sun is the best studied star in the whole Universe: we can measure its properties with accuracy like no other star. However, all this information just tells us about how the Sun looks like now. To understand the past, and future, evolution of the Sun, including its wind, magnetism, activity, rotation, and irradiation, we rely on stellar data, in an effort to better place the Sun and the solar wind in a stellar context. In this talk, I will review the long-term evolution of the solar wind (eg, its mass-loss rate), including the evolution of observed properties that are intimately linked to the solar wind: rotation, magnetism and activity. I will also briefly discuss implications of the evolution of the solar wind on the evolving Earth. I argue that studying exoplanetary systems could open up new avenues for progress to be made in our understanding of the evolution of the solar wind.

KEYWORDS solar and stellar wind, magnetism, rotation, stellar activity

IAUS 372
#1465

Stirring the Base of the Solar Wind

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Current models of the solar wind must approximate (or ignore) the small-scale dynamics within the solar atmosphere, however these are likely important in shaping the emerging wave-turbulence spectrum and ultimately heating/accelerating the coronal plasma. In this talk, I will make connections between small-scale vortex motions at the base of the solar wind and the resulting heating/acceleration of coronal plasma. We apply the Bifrost RMHD code to produce realistic simulations of the solar atmosphere that facilitate the analysis of spatial and temporal scales which are currently at, or beyond, the limit of modern solar telescopes. The simulation is configured to represent the solar atmosphere in a coronal hole region, from which the fast solar wind emerges. The simulation extends from the upper-convection zone (2.5Mm below the photosphere) to the low-corona (14.5Mm above the photosphere), with a horizontal extent of 24Mm x 24Mm. Photospheric flows are found to efficiently twisted the coronal magnetic field, with Poynting fluxes of up to 2-4kW/m^2 commonly observed inside the twisted structures. Stronger whirlpool-like flows in the convection, concurrent with magnetic concentrations, launch torsional Alfv\'en waves up through the magnetic funnel network, which are expected to enhance the turbulent generation of magnetic switchbacks in the solar wind. Temperature and density contrasts form between regions with active stirring motions and those without. Therefore, stirring motions in the low-corona represent one possible explanation for the patchy nature of switchbacks in the solar wind, observed by Parker Solar Probe.

KEYWORDS Solar, Wind, Heating, Bifrost, Vortex, Switchbacks

IAUS 372
#517

Exploring the formation solar wind, switchbacks and Quiet Sun heating

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The solar wind formation, acceleration, and solar coronal heating are intimately tied by the prevailing magnetic field topology and the energy deposition mechanism in the solar atmosphere. This dichotomy is seen as excess (reduced) blueshifts (intensity, redshifts) in Coronal holes (CH) over nearby Quiet Sun (QS) regions in the corona. These differences are seen in the transition region (TR) seen only for regions with similar photospheric magnetic flux density (|B|). In this work, we study the chromospheric Mg II h&k, the C II 1334 Å, and the TR Si IV line in CHs and QS as a function of |B|. We find all lines to show an increase of intensities and velocities with |B|. The chromospheric lines show reduced intensity, excess blueshifts, and excess redshifts in CHs over QS for regions with similar |B|. In the TR line, CHs show excess blueshifts and reduced intensity and redshift. We then perform cross-correlation of chromospheric and TR velocities to explore the dichotomy of redshifts across heights. The exercise shows that flows in the same direction are tightly correlated in both regions, while the chromospheric downflows are also correlated with TR upflows. The TR downflows (upflows) are larger in QS (CHs) for similar chromospheric flows. These results may be explained through impulsive heating in a stratified atmosphere causing larger deceleration (acceleration) of downflow (upflow) in QS (CHs), which form due to bidirectional flows generated by impulsive events. The observed flows and intensities may be explained by invoking interchange (closed-loop) reconnection in CHs (QS). Furthermore, our results provide constraints on the formation of switchbacks in the lower atmosphere. These results demonstrate the importance of high spatial, temporal, and spectral resolution observations of quiescent regions in understanding the mass and energy transport across the solar atmosphere and are important in the context of future missions like Aditya-L1, MUSE, SPICE, and EUVST.

KEYWORDS solar wind, coronal heating, coronal hole, interchange reconnection, switchbacks, solar chromosphere, solar transition region

IAUS 372
#2795

First science with Solar Orbiter Metis coronagraph

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Metis is the coronagraph on board Solar Orbiter, that provides images of the extended solar corona in the broadband VL (580-640 nm) with polarimetric capabilities and, simoultaneously, in the narrowband HI Ly-alpha at 121.6 nm. Owing to the eccentricity of the spacecraft orbit, the FoV will cover a variable annular region from 1.7 to 9 solar radii with unprecedented spatial (2000 km) and temporal resolution (1s). The near-Sun multi-wavelength coronal imaging performed with Metis, combined with the unique opportunities offered by the Solar Orbiter mission, will address key issues such as: the acceleration of the fast and slow solar wind streams; the transient ejection of coronal mass and its evolution; the large scale magnetic morphology of the solar corona; and the origin of the solar energetic particles, thus, improving the understanding of the region connecting the Sun to the heliosphere. Metis is operating and will operate in synergy with present and future space- and ground-based solar observatories providing a multi-messanger, multi-spacecraft and multi-point-of-view insight of the solar corona. VL total brightness and linearly polarized images combined with HI images allow us to determine the physical properties, such as dentities and velocities, of the two major constituents of the solar corona: hydrogen and electrons, and obtain a characterization of the F-corona, produced by the scattering of interplanetary dust grains.

Solar Orbiter mission entered the nominal mission phase at the end on November 2021 and Metis observed almost continuosly since the cruise phase. A summary of the main results obtained by Metis is given: on the determination of the solar wind speed by means of the Doppler dimming technique, the analysis of transient phenomena like CMEs and filament eruption, coronal density fluctuations. A review of the present in-flight calibration will also be provided together with the coordination and synergies with present missions (SOHO, STEREO, and PSP) and future missions (PROBA3/ASPIICS, Aditya).

KEYWORDS solar corona, solar wind, coronagraph, K-corona, HI Lyman-alpha corona

IAUS 372
#2480

Solar Orbiter/EUI very wide field observations of the EUV corona

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At 3.8°, the field of view (FOV) of the Full Sun Imager (FSI) on Solar Orbiter is by far wider than that of any previous solar EUV imager. Depending on the distance of the probe to the Sun along its orbit, this corresponds to 14 to 4 solar radii, to be compared to the 3.5 Rs of STEREO/EUVI or Proba2/SWAP. This very large field of view opens up a new discovery space into a region largely unexplored in the EUV. Since it was expected that stray-light would dominate beyond 2 Rs, a moveable occulting disk can be inserted in the optical path to block light rays up to 0.78° off the optical axis. On March 21 2021, at 0.51 AU, FSI acquired deep exposures at 17.4 and 30.4 nm with the occulting disk in place. The data reveals solar structures extending up to 5 Rs which, to our knowledge, is the furthest ever recorded at these wavelengths. We compare the morphology of the observed structures with close in time observations in white light by the Metis coronagraph. We present a comparison of the measured signal fall-off as a function of distance to Sun-center with a model of coronal emission taking into account collisional excitation and resonant scattering.

KEYWORDS Sun, Solar Orbiter, EUV, Corona

IAUS 372

#1282

The heliosphere in 3D from multi-spacecraft observations

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There is now an amazing fleet of spacecraft present in the inner heliosphere that is bound to revolutionize our current understanding of how the Sun shapes the heliosphere. It is the combination of in situ and remote sensing data from Solar Orbiter, Parker Solar Probe (PSP), BepiColombo, STEREO-Ahead and SOHO, ACE, Wind and DSCOVR in near-Earth space that allows us to discover new processes and to check where and how our simulations and models fail, and how to improve them. These multi-messenger observations are much needed to make progress on the understanding of many unsolved problems, for example concerning the global magnetic configuration of coronal mass ejections and high-speed solar wind streams, real-time space weather forecasting, the magnetic connectivity of the solar wind to the Sun, and the propagation of solar energetic particles. I will present an overview of some recent discoveries and the development of innovative methods. Additionally, event catalogs that have been meticulously built up in the last few years provide a quick entry for validating simulations without the need to comb through the data first. I will then present an outlook on whats to come in this decade, from PSP routinely crossing the the Alfvén surface, the possibility that PSP crosses a CME close to the Sun twice, to how Solar Orbiter improves ambient solar wind modeling by imaging the solar poles, and provide much anticipated additional data by in situ instruments away from the ecliptic. The upcoming PUNCH mission will allow for the first time to extract 3D information from heliospheric images. All these unique observations in the solar wind will also help to deepen our knowledge of stellar CMEs. These novel results and methods are then expected to lay the groundwork for real-time application through data by the ESA Vigil mission, a dedicated space weather outpost at the Sun-Earth L5 point, planned to be launched by the end of the decade.

KEYWORDS heliophysics, solar wind, space weather, coronal mass ejections, high-speed solar wind streams, solar energetic particles

IAUS 372
#916

CME-CME interaction in the interplanetary space: Observation and simulation

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To understand CME-CME interaction in the interplanetary space, we investigated solar wind observation near-Earth space including solar radio burst, proton event, and ICME's arrival, and compared to EUHFORIA simulation. For this, we selected 6 isolated CME-CME pairs which are expected to meet near-Earth based on their ejecting time and propagating speed. Assuming that their interaction phase can be inferred from the time difference of preceding and following CMEs' expected arrivals at the Earth, we found that (1) there can be reverse drifting in the radio spectrum meaning density increase for the events in the phase of just before and during the interaction. (2) Also, in that phase, there can be magnetic hole structures separating two magnetic clouds, which are characterized by abrupt change and subsequent recovery in the solar wind condition such as density and magnetic field. (3) The thicknesses of the sheath and magnetic cloud have strong linear relationships with the arrival time difference, and this can be explained by the elongated components due to the interaction. Based on the observation and the EUHFORIA simulation results, it can be inferred that as the two CMEs get closer, the interaction starts with density increase in the solar wind and a magnetic hole is formed, and then finally the interaction ends as the thickness of the sheath and the magnetic cloud gradually thickens.

KEYWORDS CME, solar wind, ICME, EUHFORIA, solar radio burst, solar proton event, magnetic cloud

IAUS 372

#2246

2Pi steroradian radio observations of the 28-10-2021 solar flare

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Type III radio bursts are causally associated with solar flares. The energy stored in the coronal magnetic fields when released heats plasma and accelerates electrons and ions to high energies. Interplanetary radio emission is produced by flare accelerated electron beams interacting with ambient plasma as they propagate in the interplanetary medium. On 28 October 2021 a X1 GOES Class solar flare (SOL2021-10-28) was observed by several heliophysics observatories, in particular, by the Solar Dynamics Observatory (SDO), Parker Solar Probe (PSP), Solar Orbiter (SolO) and the Solar TErrestrial RElations Observatory (STEREO). We report the results of the radio flux and radio direction-finding analysis and their possible implications for the process of generating radio emission from the electron beams associated with the bursts.

KEYWORDS Flares, Type III

IAUS 372
#2381

A revisit to the source regions of solar energetic particles by the synchronic potential field source surface model

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We revisit magnetic field configurations of the source regions of 6 solar energetic particle (SEP) events accelerated near or behind the limbs. For this, we use a new potential field source surface model (AI-PFSS) at $2.5R_\odot$, on a near real-time basis using AI-generated farside magnetograms by Jeong et al. (2020). By comparing AI-PFSS and conventional PFSS from HMI synoptic data (HMI-PFSS), we find several interesting differences on the SEP source regions and their magnetic field configurations between them. 1) The structure and size of source active regions (ARs) are significantly changed. The total unsigned magnetic field fluxes of the ARs are mostly stronger in AI-PFSS rather than HMI-PFSS except for one case. 2) In particular, newly emerging ARs are observed near the SEP source regions in the AI-PFSS for two cases. The locations of the emission features in the full-sun EUV synchronic maps are consistent with ARs in the AI-PFSS. 3) The inversion lines are changed due to the appearance and/or disappearance of ARs. The propagation directions of the source eruptions in the running difference EUV images are consistent with the configurations of the inversion lines in the AI-PFSS. This study shows that AI-PFSS is able to give a better understanding of SEP source regions and their magnetic field connections.

KEYWORDS Solar energetic particle, CME, flare, PFSS

IAUS 372
#980

Complete restructuring of a magnetic flux rope during a solar eruption

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Solar eruptions are magnificent and energetic explosions in the heliosphere, among which the magnetic flux rope is a fundamental structure. In the standard model, a magnetic flux rope builds up into a CME through magnetic reconnection that continually converts the overlying, untwisted magnetic flux into twisted flux enveloping the pre-existent rope. However, only about one third of in-situ detected CMEs have the flux-rope configuration, which casts doubt on the universality of such a well-organized enveloping process. Here we present observations of the complete restructuring of a pre-forming flux rope during its eruption. The formation process is featured by the growth of a hot seed and simultaneous slipping and expansion of its footpoint into being enclosed by a trapezoid-shaped ribbon. During the subsequent eruption, the flux rope's feet migrate to new places, indicative of a complete replacement of magnetic fluxes in the original flux rope. Our study signifies the three-dimensional reconnection between the flux rope and the surrounding magnetic fields, and provides new clues for the development of the CME.

KEYWORDS coronal mass ejection, solar flare, magnetic reconnection, solar eruption, magnetic flux rope

IAUS 372

#2730

Understanding solar local dynamo

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Solar local dynamo is the process which is believed to be responsible for the appearance of the magnetic fields of the quiet Sun. It operates at the near surface layers of the solar envelope. High resolution realistic simulations of solar convection reproduce the action of the local solar dynamo, with the magnetic field growing from a small seed value toward the saturated value of about 10^2 G, which is apparently close to the one observed in the quiet Sun. There are however controversial results as for the conditions required for the dynamo to work in the numerical models, since none of the current models reach the realistic Reynolds or Prandtl numbers. At the same time, there is yet no agreement as for the cycle dependence of the quiet Sun magnetic fields. Observations of magnetic flux recirculation, a dynamical process underlying the local dynamo, have not been yet obtained at the required resolution. This talk will summarize our current observational and theoretical understanding of solar local dynamo, and future challenges to be addressed by high resolution data from new instruments and missions.

KEYWORDS Sun, Dynamo, Simulations, Observations, Photosphere, Interior

IAUS 372
#2508

Plasma heating along a current sheet in nonequilibrium ionization and non-Maxwellian electron velocity distribution

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We investigate plasma heating along a current sheet considering nonequilibrium ionization states and non-Maxwellian electron velocity distributions. We assume continuous heating as the plasma expands after rapid heating at the beginning of the eruption. We calculate ion fractions solving a time-dependent ionization equation with various Kappa values, representing non-Maxwellian electron velocity distributions, with the heated temperatures. Then, we simulate the count rates using the calculated ion fractions and compare them with the observations on 2017 September 10 by the Atmospheric Imaging Assembly on board the Solar Dynamic Observatory. Finally, we discuss the heating rates and Kappa values that satisfy the observations. This could guide the studies on other solar events considering the nonequilibrium states.

KEYWORDS Solar Corona, Coronal Mass Ejection, Nonequilibrium ionization, Kappa electron velocity distribution

IAUS 372
#292

Why Are Solar Prominences Filamentary?

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Solar prominences are cool and dense structures suspended in hot and tenuous solar corona. They are of the shape of ribbons or a stack of threads, and thus are also called solar filaments. It has been thought that the prominence material is formed by thermal condensation instability of optically thin, hot coronal plasma. Although the conventional thermal instability theory can explain contraction of gas volume by cooling, it can hardly explain why the cooled gas has filamentary substructures. An interesting, but poorly understood observation in solar prominences is ubiquitous counter-streaming flows along their filamentary fine structures. Although thermal instability in optically thin plasmas has quite extensively been studied in various situations, it has rarely been studied in relation to shear flows. In this paper, we present a study on thermal instability in magnetized plasmas with shear flows based on linear stability analysis. We have found that for sub-Alfvenic shear flows, the density and temperature eigenfunctions of condensation modes (thermally unstable modes) are of the form of delta functions unless the shear velocity is extremely small (a millionth of the Alfven velocity), and the condensation takes place only in discrete sheets. For a super-Alfvenic shear velocity, a Kelvin-Helmholtz instability sets in as is well-known, and no thermal instability arises. In this regard, it is to be noted that the counter-streaming flows observed in solar prominences are always sub-Alfvenic. Our results indicate that any non-uniform velocity field with a shear magnitude larger than 10 m/s in the solar corona can generate discrete eigenfunctions of the condensation mode. We therefore suggest that filamentary condensation (condensation at discrete layers or threads) should be quite a natural and universal process whenever a thermal condensation instability arises in magnetized plasmas with any unignorable velocity shear.

KEYWORDS solar prominences, thermal condensation instability, filamentary structures, shear flows, magnetized plasmas

IAUS 372
#2249

Formation of activity indicators in a 3D model atmosphere

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The Sun, being the nearest star, can be used as a reference case for solar-like stars due to the availability of many spatiotemporally resolved solar spectra. Amongst several spectral lines, some of the strongest chromospheric diagnostics are the Ca II H & K lines which can be used to gauge the temperature stratification of the atmosphere as the line core and wings are formed in different regions of the solar atmosphere. Furthermore, the H α line is a tracer for the magnetic structures and its line core gives an estimate of the mass density. These two diagnostics together can provide insights into the stellar structure.

The 1.5D radiation transfer codes RH and Multi3D are used to obtain synthetic spectra for the Ca II lines and the H α line from an enhanced network atmosphere model simulated with the state-of-the-art Bifrost code. The activity indices generated from these lines could further be used to compare the spectra of sun-like stars with the solar spectrum. These indices can shed light on the physical properties like temperature stratification, magnetic structures, mass density distribution in the stellar atmospheres. Meanwhile, brightness temperatures from ALMA observations provide a new complementary view on the activity and the thermal structure of stellar atmospheres. The synthetic Ca II and H α spectra are therefore compared to corresponding millimetre continuum maps. The overall aim of the presented study is to establish more robust solar/stellar activity indicators using ALMA observations in comparison with classical diagnostics.

KEYWORDS activity index, mm indicators, solar physics, simulations, Ca II H & K, H alpha, spectral lines

Detection of Propagating Alfvenic Waves in the Solar Chromosphere

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Alfvenic waves are regarded as an important process in understanding coronal heating, solar wind acceleration, and the fractionization of low first-ionization-potential (FIP) elements. Recently, significant progress has been made in the detection of propagating Alfvenic waves in the solar chromosphere using two different methods: the imaging method and the spectroscopic method. The imaging method detects Alfvenic waves that oscillate in the direction perpendicular to the line of sight, and the spectroscopic method, those that oscillate in the line of sight direction. We have applied the spectroscopic method to the imaging spectral data taken by the FISS on GST at Big Bear. As a result, we detected a number of propagating Alfvenic wave packets and found that there are two distinct groups: three-minute period waves, and ten-minute period waves. We propose two tales on the origin of Alfvenic waves in the chromosphere; the three-minute waves are excited by the upward-propagating slow waves in the chromosphere through mode conversion, and the ten-minute waves represent the chromospheric manifestation of the kink waves driven by convective motions in the photosphere.

KEYWORDS Solar Chromosphere, Alfven waves, Spectroscopy, Magnetohydrodynamics, Solar atmosphere

IAUS 372

#1961

Application of Deep Learning to Solar and Space Weather Data

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In this talk, we introduce our recent applications of deep learning to solar and space weather data. Our major applications are (1) generation of solar farside magnetograms and global field extrapolation, (2) generation of solar UV/EUV images, (3) denoising solar magnetograms, (4) generation of modern satellite images from Galileo sunspot drawings, (5) improvement of global IRI TEC maps, (6) one-day forecasting of global TEC maps, (7) generation of high-resolution magnetograms from Ca II K images, (8) generation of super-resolution magnetograms, (9) flare classification and visual explanation, and (10) forecasting solar X-ray profiles. We also discuss future plans for integrated space weather models based on deep learning.

KEYWORDS solar, space weather, deep learning, image translation

IAUS 372

#833

Heliophysics Events Knowledgebase support for Multi-Messenger Solar Physics

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Modern studies of the Sun involve coordinated observations collected from a collage of instruments on the ground and in orbit. Each instrument has its own constraints, such as field of view, duty cycle, and scheduling and commanding windows, that must both be coordinated during operations and be discoverable for analyses of the resulting data. Details on the observed solar features, i.e. sunspots or filaments, and solar events, i.e. flares or coronal mass ejections, are also incorporated to help guide data discovery and data analysis pipelines. The Heliophysics Events Knowledgebase (HEK) provides a standards-based system for collecting and presenting observations collected by distributed, ground and space based solar observatories and cross referencing them with solar phenomena. The HEK currently supports all instruments on the Interface Region Imaging Spectrograph (IRIS) and Hinode missions as well as associated ground-based observatories. The flexible design of the HEK is capable of supporting other data and events such as heliospheric imagers and in situ events. Here we review the tools the HEK provides scientists to record solar observations, enable flexible searches on observation metadata and solar features and events.

KEYWORDS Solar Physics, Heliophysics, Multi-messenger

IAUS 372
#2078

Deep neural network estimator for image refinement and estimation on radiation formation heights

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The point spread function generally constitutes the resolution element in astronomical observations, which degrades the intensity contrasts and leaving structures at smaller angular resolution unresolved. The solar atmosphere is highly dynamic and the intensities and height of formation of the radiation is strongly connected to the small scale dynamics, which is utilised in the current work to perform estimations and improve the analysis of solar observations.

An artificial deep neural network is trained to recognise dynamic patterns of features in both the spatial and temporal domains, to perform estimations on the intensity contrast degradation and the height of formation of the radiation. The neural network is trained on radiative transfer calculations from 3D MHD Bifrost simulations of the solar atmosphere and is applied to perform estimations on millimeter wavelength observations with ALMA to acquire more precise intensities and corresponding height of formation.

The deep neural network can to large accuracy distinguish whether a brightening event or feature is well resolved and to what degree it is over or underestimated. Using this method as a diagnostics tool for small-scale dynamics in solar ALMA observations, where the intensity is closely related to the plasma temperature, enables to study the potential heating at small scales of different layers of the upper solar atmosphere.

KEYWORDS machine learning, artificial intelligence, simulations, radiative transfer, imaging, image enhancement, formation height

IAUS 372
#500

Automatic Extraction of Solar Filaments Using Machine Learning Techniques

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Filaments are omnipresent features in the solar chromosphere. Regular full-disk H-alpha observations allow us to analyze statistical properties of filaments. Therefore, filaments have to be extracted from the images. Manual extraction is tedious and takes too much time; extraction with morphological image processing tools produces a large number of false-positive detections. Automatic object detection and extraction in a reliable manner allows us to process more data in a shorter time. The Chromospheric Telescope (ChroTel), Tenerife, Spain, the Kanzelhöhe Solar Observatory (KSO), Austria, and the Global Oscillation Network Group (GONG), provide regular full-disk observations of the Sun in the core of the chromospheric H-alpha absorption line. We will present a machine learning application allowing us to reliably extract solar filaments from H-alpha filtergrams. First, we train the object detection algorithm YOLOv5 with labeled filament data of ChroTel H-alpha filtergrams. The accuracy of the object detection is very high and it is possible to apply the algorithm to other H-alpha filtergrams to create a larger training data set for the further steps. In a second step, we apply a semi-supervised training approach, where we use the bounding boxes of filaments, that were created with YOLOv5, to learn a pixel-wise classification of solar filaments. Therefore, we utilize a standard deep learning model for semantic segmentation, i.e., DeepLabv3. With the resulting segmentation masks, physical parameters such as the area or tilt angle of filaments can be easily determined and studied. In a last step, we apply the filament detection and the segmentation of filaments on a different H-alpha data set belonging to ChroTel, KSO and GONG, to estimate the general applicability of our method.

KEYWORDS Sun, Filament, Object Detection, Machine Learning, Chromosphere

IAUS 372
#597

Generation of coronal white light images from SDO/AIA EUV images using deep learning

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Solar white light observations are very important to understand the low coronal features, but they are rarely made. We generate the MLSO K-coronagraph like white light images from SDO/AIA EUV images using a deep learning model based on conditional generative adversarial networks. We train the model using pairs of MLSO K-coronagraph images and their corresponding SDO/AIA EUV (171, 193 & 211Å) images considering the field of view between 1.11 to 1.25 solar radii. For this image translation, we made seven (single channels and combination of multiple channels) deep learning models. Our results from the study are summarized as follows. First, the multiple channel 'AIA 193 & 211Å' model is the best among seven models in-view of metrics such as correlation coefficient and normalized root mean square error. Second, major low coronal features like helmet streamers, pseudo-streamers and polar coronal holes are well identified in the AI-generated images by this model. The positions and sizes of the polar coronal holes of the AI-generated images are consistent with those of the target ones. Third, from AI-generated images, we successfully identified a few interesting phenomena: jets and CMEs. We hope that our model provides us with complementary data to study the low coronal features in white light during non-observable cases (during night-time, poor atmospheric conditions and instrumental maintenance).

KEYWORDS Solar Corona, White Light, EUV, MLSO, SDO/AIA, Coronal Holes, Streamers

IAUS 372
#1194

Modeling efforts for multi-mission science

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The Solar Orbiter spacecraft, launched in February 2020, is equipped with both remote-sensing (RS) and in-situ (IS) instruments to record novel and unprecedented measurements of the solar atmosphere and the inner heliosphere. To take full advantage of these new datasets, we have developed tools and techniques to ease multi-instrument and multi-spacecraft studies that will be presented here. In particular the yet inaccessible low solar corona below two solar radii can only be observed remotely and techniques must be used to retrieve coronal plasma properties in time and in 3-D space. These properties are useful to drive numerical models and test the different theories proposed to describe the fundamental processes of the solar atmosphere. In addition, the last decades of research have shown that the coupling between the solar corona and the heliosphere is most efficiently studied by combining RS with IS data. During the last remote sensing windows, planned for the Solar Orbiter instruments, we ran complex observation campaigns to maximize the likelihood of linking IS data to their source region near the Sun, by directing some RS instruments to specific targets on the solar disk just days before data acquisition. We will present the results of these efforts directed to improve our understanding of how heliospheric probes connect magnetically to the solar disk.

KEYWORDS Sun, Connectivity, Solar Orbiter, Magnetic field, Solar atmosphere, Solar corona, Heliosphere

IAUS 372
#1725

Coordinating Solar Orbiter Operations: The Story so far and What to Expect Next

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After a Cruise Phase of 21 months, Solar Orbiter began its first scientific orbit on 27 November 2021 with a Gravity Assist Manoeuvre (GAM) by the Earth. The spacecraft entered a highly elliptical orbit that took it past its first close perihelion on 26 March 2022, some 0.32AU from the Sun. In the following years, further GAMs by Venus will lead it even closer to the Sun and also out of the ecliptic plane to give us our first view of the Sun's poles.

Solar Orbiter's main goal is to study the connection between solar activity close to our star's surface and its effects as seen in the heliosphere, the bubble-like region of space under the Sun's influence including all solar planets. Therefore, its main scientific goals can only be achieved by coordinated observations of both the 6 remote-sensing telescopes on board, observing the dynamic Sun, and the 4 in-situ instruments measuring the effects in the solar wind surrounding the spacecraft.

This coordination takes careful planning and optimisation of the mission resources in order to fully exploit the capabilities of this exciting mission, and the fantastic opportunities for Solar Orbiter to work together with other missions, including Parker Solar Probe and DKIST. Here, we explain how this is done, how you can contribute, and what's planned for the second close perihelion and beyond.

KEYWORDS Sun, Solar Wind, Solar Orbiter, Operations, Heliosphere

IAUS 372

#2647

DKIST Coordination: Status and Current Strategies

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Co-Observing efforts have a long-standing tradition at the National Solar Observatory (NSO). The NSO's new high-resolution flagship the National Science Foundation's (NSF) Daniel K. Inouye Solar Telescope (DKIST) currently in its Operations Commissioning Phase will follow this tradition building on the lessons learned and challenges encountered during its transition into regular operations and beyond. In this presentation we will provide an overview of the status of these science enhancing synergies and discuss future strategies.

KEYWORDS

IAUS 372

#1927

Progresses of ASO-S mission

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The Advanced Space-based Solar Observatory (ASO-S) is a comprehensive solar observatory, the first in its category of China's space missions. The main scientific objectives of ASO-S are solar flares, coronal mass ejections (CMEs), solar magnetic field, and their relationship. Three scientific payloads (FMG, LST, and HXI) are deployed onboard the ASO-S to simultaneously observe full-disk solar vector magnetic field, solar hard X-ray bursts, and Lyman-α images up to 2.5 solar radii. ASO-S observations will also provide support for space-weather forecasts and warnings of hazardous events. The mission is now in Phase D and scheduled for launch in October 2022. A brief introduction to the scientific objectives, the payloads, and the status of the mission will be presented in this talk.

KEYWORDS Sun: Magnetic field, Sun: Flares, Sun: CMEs, Sun: space mission, Sun: X-rays, Gamma-rays, Solar activities, Space weather

IAUS 372
#2562

Spatio-temporal Characterization of Hot Chromospheric Fibrils

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The exact mechanisms leading to chromospheric heating are still ill-defined. While the presence of magnetic elements is undoubtedly necessary, the details of the heating, and its spatio-temporal distribution remain poorly understood.

We contribute to this topic by analyzing the behavior of hot chromospheric fibrils surrounding network and plage elements, identified via the broader H-alpha profiles observed along their length; the H-alpha line width parameter has indeed been previously shown to correlate with the local chromospheric temperatures through comparison with ALMA millimeter-continuum brightness temperatures. We make use of loop tracing and analysis software to investigate fibrils' characteristics including their length, number density, transverse spatial extension and proximity to magnetically active regions, as well as their dynamical properties. Finally, we discuss how understanding of these features can benefit from combined observations with complementary diagnostics as provided by ALMA and SPICE on Solar Orbiter, as well as from observations obtained at different vantage points.

KEYWORDS chromosphere, fibrils, heating, coordinated observations

IAUS 372

#2560

Generation of He I 1083nm Images from SDO AIA Images using a Deep Learning Model

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In this study, we generate He I 1083 nm images from Solar Dynamic Observatory (SDO)/Atmospheric Imaging Assembly (AIA) images using a novel deep learning method (pix2pixHD) based on conditional Generative Adversarial Networks (cGAN). He I 1083 nm images from National Solar Observatory (NSO)/Synoptic Optical Long-term Investigations of the Sun (SOLIS) are used as target data. We make three models: single-input SDO/

AIA 19.3 nm image for Model I, single-input 30.4 nm image for Model II, and double-input (19.3 and 30.4 nm) images for Model III. We use data from 2010 October to 2015 July except for June and December for training and the remaining one for test. Major results of our study are as follows. First, the models successfully generate He I 1083 nm images with high correlations. Second, Model III shows better results than those with one input image in terms of metrics such as correlation coefficient (CC) and root mean square error (RMSE). CC and RMSE between real and synthetic ones for model III with 4 by 4 binnings are 0.88 and 9.49, respectively. Third, synthetic images show well observational features such as active regions, filaments, and coronal holes. This work is meaningful in that our model can produce He I 1083 nm images with higher cadence without data gaps, which would be useful for studying the time evolution of the chromosphere and transition region.

KEYWORDS Sun, CNN, Deep learning

IAUS 372

#2264

Coronal condensation in magnetic dips as the source of quasi-steady supersonic downflows into sunspots

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With the launch of the Interface Region Imaging Spectrograph (IRIS), transition region (TR) downflows at supersonic speeds have been commonly detected above most sunspots. In IRIS spectra, these supersonic downflows (SDs) are often observed as strongly redshifted secondary emission peaks with a speed of ~100 km/s and last for at least several hours. However, how these long-lived supersonic downflows form and what mechanisms are responsible for the substantial and stable mass supply remain unclear since their first discovery in the 1980s. With multi-messenger joint observations from IRIS and several other telescopes at multiple vantage points, a series of TR SDs in NOAA AR 12740 and their associated coronal dynamic processes were investigated. The formation of a quasi-steady SD event was tracked for the first time. Dual-perspective EUV imaging observations reveal that these downflows originate from the cooling and condensation of hot coronal plasma at magnetic dips along a large-scale closed magnetic loop system spanning the sunspot region and a remote region. In the magnetic dip region, condensed materials soon accumulate as a transient prominence in the dip region and thus form a mass reservoir available to feed a long-lasting rain flow. As the rain persistently drains into the sunspot along different trajectories in funnel-like magnetic structures (sunspot plumes), the funnel effect of this magnetic geometry further reshapes the clumpy rain at the coronal height into a more elongated and stream-like one when reaching the lower atmosphere, leading to the quasi-steady SDs. In the dip region, the total mass of condensation and condensation rate were found to be large enough to sustain this long-lived SSD event. As downflows fall into the sunspot, they eventually impart their energy into the lower atmosphere of sunspots and result in a long- lived localized brightening in the umbra. This indicates that SDs play an important role in the chromosphere-corona mass cycle of the sunspot atmosphere. Based on imaging observations and magnetic field extrapolations, a reconnection-facilitated coronal condensation scenario was proposed to interpret all these results.

KEYWORDS Sunspot, Sun:chromosphere, Sun:transitionregion, Sun:corona, Sun:magneticfields

IAUS 372
#2253

Fast generation of 3D solar coronal parameters based on MAS by a deep learning method

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Modeling of the three-dimensional structure of the solar corona requires an accurate empirical description of the coronal plasma parameters like density, magnetic field, and temperature. Magnetohydrodynamic (MHD) models provide a quantitative 3D distribution of the magnetic field and the plasma parameters in the solar corona. This study is the first attempt to generate 3D coronal parameter distributions using a well-known deep learning model. We consider synoptic photospheric magnetic fields as an input to obtain 3D solar coronal parameters. 4272 pairs of inputs and outputs are considered for training, validation, and testing from 2010 June to 2020 May, which is simulated with the MHD Algorithm outside a Sphere (MAS) model. We train 54 separate deep learning models to cover from 2 to 30 solar radii for solar coronal parameters. The generated 3D solar parameters are consistent with those of the simulated ones at not only lower solar radii but also higher radii with high mean correlation coefficients (0.98). The most impressive result is that the computing time of the 54 models for each solar coronal parameter is about 35 secs under NVIDIA TITAN XP GPU, which is much less than a typical simulation time of MAS. Our study shows that the synthetic coronagraphic images estimated from the deep learning models are similar to the SOHO/LASCO C3 images, especially during solar minimum period. We have a plan to use synchronic magnetic field data from SDO/HMI and AI-generated farside magnetograms as input data. The generated coronal density distribution can be used for space weather models on a near real-time basis.

KEYWORDS Solar corona, Astronomy data analysis, Deep learning, Image processing

Dynamical and Thermal Properties of RBEs and RREs derived from Fast Imaging Solar Spectrograph

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A rapid blueshifted excursion (RBE) or rapid redshifted excursion (RRE) is appeared as a 'sudden widening of the line profile' on the blue or red side of the line, following the definition given by Langangen. RBEs are often regarded as on-disk counterparts of Type II spicules based on their rapid upward Doppler speed (~40km/s) without following downward motion. On the other hand, there are some reports on the transition from RBEs to RREs indicating material falling back after ejections. We observe tiny spicular features that show a spectral shift from RBE to RRE in an enhanced network field of a quiet Sun region, using the fast imaging solar spectrograph built at the Goode Solar Telescope of Big Bear Solar Observatory. Two strong chromospheric lines, Hα and CaII 854.2 nm, are used for spectroscopy. Multi-layer spectral inversion technique is applied to both lines to obtain spectral parameters, including line-of-sight velocities and temperatures in time. Two events of our interests reveal spectral transitions from RBEs to RREs, with corresponding IRIS counterparts that clearly show the parabolic up and down motion. We also detected intensity enhancements in AIA 193 and 304 channels at the early phase of RBEs, indicating possible heating at the time of ejections. The temperature of the spicular structure shows a monotonic decrease during the RBE phase suggesting continuous cooling after the energy deposit. We could not find any heating signatures after the RBE phase that is normally expected from type II spicules, and both RBE events we analyze show typical properties of small-scale jets.

KEYWORDS solar activity, solar atmosphere, solar chromosphere, solar spicules

IAUS 372

#1780

How density profiles of global coronal waves influence their interaction with coronal holes

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Interactions between global coronal waves (CWs) and coronal holes (CHs) reveal many interesting features about reflected waves and coronal hole boundaries but have fairly been studied so far. Among the reasons for the lack of observational studies are for example the weak signal of the reflected waves and the only limited time cadence which prevents us from analysing the CWs in detail. However, magnetohydrodynamic (MHD) simulations can help us to better understand what is going on during these interaction events, and therefore, to achieve a broader understanding of the parameters involved in these interactions. It is particularly crucial to interpret and understand the observational time-distance plots which give us important information about the dynamical behaviour of the incoming and the reflected waves. By using numerical simulations, we are capable of partially reconstructing the interaction event, and hence, to find out which CW parameters cause certain interaction features. One important result about the reconstruction and the direct comparison to the observations is the fact that, in order to explain the main features of the interaction event, it seems to be necessary to define the incoming wave in the simulations as a composite of a density enhancement and a subsequent depletion instead of considering the wave as a purely enhanced pulse, as it has been done in many studies so far. This result does not only have implications for the interaction with CHs but also for the interaction with any other obstacle in the corona, such as for example prominences. Therefore, we believe that it is crucial to consider the density profiles of global CWs in future MHD simulations of coronal dynamics.

KEYWORDS global coronal waves, coronal holes, MHD simulations

IAUS 372
#1634

The Coronal Solar Magnetism Observatory (COSMO)

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Magnetism is the dominant force in the solar corona. It plays a key role in structuring the corona on all spatial scales, in heating the corona, and accelerating the solar wind. The storage and release of magnetic free energy in the corona powers solar eruptions that are responsible for space weather with serious consequences for our technological society. Daily synoptic measurements of the magnetic structure of the global solar corona are needed to advance our understanding of these critical physical processes and to enable a predictive capability of solar eruptive events.

The lack of synoptic measurements of global coronal magnetism is due to a technology gap in our current capabilities. One pathway to bridge this gap is to observe the Zeeman and saturated Hanle effects of forbidden emission lines in the visible and IR portions of the coronal spectrum with a ground-based coronagraph. The IR has the advantage that the Zeeman splitting scales as the wavelength squared. A dedicated, high-throughput coronagraph/polarimeter that combines a large aperture with a large field of view is needed to observe the weak circular polarization signals and monitor the evolution of coronal magnetism. The Coronal Solar Magnetism Observatory (COSMO) Large Coronagraph represents a proposed instrument able to meet this technological challenge, complementing the recently built Daniel K. Inouye Solar Telescope that has a large aperture and high spatial resolution, but is limited in FOV and is not a dedicated coronal facility. The COSMO-LC joins the COSMO K-Coronagraph (K-Cor), currently operating at Mauna Loa, which observes the low corona in broad band light, ideal for tracking CMEs and for providing information on coronal density, and the Chromospheric and prominence Magnetometer (ChroMag), which measures magnetic field and plasma conditions below the corona using polarized light from emission lines of the chromosphere and photosphere.

The crucial plasma and magnetic measurements obtained by COSMO, in combination with in-situ particle measurements, provide a new avenue for understanding the processes that govern the storage and explosive release of magnetic free energy in the corona and enable us to protect our critical infrastructures.

KEYWORDS solar corona, magnetic field

IAUS 372

#1641

Scattering Polarization Diagnostic of the UV Corona

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The structuring of coronal plasma by the magnetic field is the key to understanding the fundamental physical processes of energy build up, storage, and release throughout the solar corona. Measurements of the coronal magnetic field vector in the global corona are thus crucial to understanding and modeling coronal dynamics and space weather. Ground-based efforts are largely limited to the observation of forbidden emission lines in the low corona. They also require large telescopes to reveal the small polarization signatures of the Zeeman effect produced by the weak coronal field.

A complementary, and largely unexplored diagnostic of the coronal magnetic field vector is offered by the linear polarization signature of the Hanle effect of far ultraviolet (FUV) resonance lines. In particular, H I Lyman-alpha offers an almost unique opportunity for a comprehensive view of the solar corona and its structuring by the magnetic field. This line's scattering polarization is sensitive to fields between a few gauss to about 100 gauss, allowing the direct measurement of closed fields above active regions and in coronal prominence cavities and arcades. At larger coronal heights and in coronal regions dominated by weaker open fields, the Lyman-alpha polarization is instead practically insensitive to the magnetic field, and it becomes a proxy for diagnosing solar wind outflows and plasma temperature anisotropies. The strong linear polarization signal produced by resonance scattering in the FUV coronal lines, and its sensitivity to the magnetic field strength and topology via the Hanle effect, make these diagnostics accessible to modest aperture (10-30 cm) telescopes, e.g., the Coronal Lyman-α Resonance Observatory (CLARO).

The crucial magnetic measurements obtained by CLARO, in combination with remote-sensing plasma diagnostics and in-situ particle measurements, provide a new avenue for understanding the processes that govern the storage and explosive release of magnetic free energy in the corona and enable us to protect our critical infrastructures.

KEYWORDS solar corona

IAUS 372

#1590

Coronal Magnetic Field Reconstruction Using the Poloidal-Toroidal Representation

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For coronal magnetic field reconstruction, quite a few numerical methods have been proposed and are being applied to practical problems. However, their outcomes are often disparately different for complex real coronal fields. One of the most difficult configurations for them to reconstruct is tightly wound flux ropes. Many extant codes produce blandly sheared fields or double crossed flux tubes in place of a single flux rope. Such problems are attributed to a loose connection between the boundary condition and the resulting field within the domain. To resolve these problems, we have devised a numerical method, in which the implementation of the boundary condition is straightforward and its influence is readily permeated into the domain. Our numerical method uses a poloidal-toroidal representation of magnetic field, which guarantees the divergence-freeness of magnetic field and allows to fix the boundary condition once and for all. The iteration scheme is non-variational and seeks a stationary solution in a direct manner. We will present and compare the solutions of our code and other extant codes for Titov-Démoulin flux ropes and some active region magnetic fields.

KEYWORDS coronal magnetic field reconstruction, poloidal-toroidal representation, solar active region

IAUS 372

#1252

Photospheric magnetic field variations during solar flares

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Solar flares are an explosive manifestation of the complex magnetic structuring of active regions in the solar atmosphere. The photospheric magnetic field is found to change rapidly, abruptly, and significantly during flaring events. Previous studies are mainly based on line-of-sight or low cadence data. In this work, we focus on the temporal and spatial evolution of the permanent changes in the magnetic field of solar flares from high-cadence vector data (135 seconds) of the imaging system (dopplergrams and magnetograms) of the SDO/HMI instrument. The highly energetic events under analysis occurred during the solar cycle 24, covering low and high energy ranges, according to GOES classification. This work stands also as a crucial input for the characterization and understanding of sunquakes.

KEYWORDS Magnetic field, Photosphere, Flares, Sunquakes

IAUS 372

#1218

Self-consistent nanoflare heating in model active regions: MHD avalanches in curved coronal arcades

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MHD avalanches involve small, narrowly localized instabilities spreading across neighbouring areas in a magnetic field.
Cumulatively, many small events release vast amounts of stored energy.
Straight cylindrical flux tubes are easily modelled, between two parallel planes, and can support such an avalanche: one unstable flux tube causes instability to proliferate, via magnetic reconnection, and then an ongoing chain of like events.
True coronal loops, however, are visibly curved, between footpoints on the same solar surface.
With 3D MHD simulations, we verify the viability of MHD avalanches in the more physically realistic, curved geometry of a coronal arcade.
MHD avalanches thus amplify instability across strong solar magnetic fields and disturb wide regions of plasma.
Contrasting with the behaviour of straight cylindrical models, a modified ideal MHD kink mode occurs, more readily and preferentially upwards in the new, curved geometry.
Instability spreads over a region far wider than the original flux tubes and than their footpoints.
Consequently, sustained heating is produced in a series of `nanoflares', collectively contributing substantially to coronal heating.
Overwhelmingly, viscous heating dominates, generated in shocks and jets produced by individual small events.
Reconnection is not the greatest contributor to heating, but is rather the facilitator of those processes that are.
Localized and impulsive, heating shows no strong spatial preference, except a modest bias away from footpoints, towards the loop's apex.
Remarkable evidence emerges of `campfire'-like events, with simultaneous, reconnection-induced nanoflares at separate sites along coronal strands, akin to recent results from Solar Orbiter.
Effects of physically realistic plasma parameters, and the implications for thermodynamic models, with energetic transport, are discussed.

KEYWORDS Sun: corona, Sun: magnetic fields, magnetohydrodynamics (MHD), methods: numerical

IAUS 372

#1006

The emerging flux meets the magnetic canopy: chromospheric heating in current sheets and cooling rates

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The interaction between emerging magnetic fields and the preexisting magnetic canopy in active regions is a complex process but essential for understanding the onset of transient brightenings driven by magnetic reconnection and their role in energy/mass deposition in the chromosphere and above. We present the results of a comprehensive analysis of SST optical/infrared spectropolarimetry and ALMA millimeter brightness temperature maps of a solar active region using nonlocal thermodynamic equilibrium inversions, magnetohydrostastic field extrapolations, and a snapshot of a 3D radiative magnetohydrodynamics simulation. Inversions of the SST+ALMA data set provide constraints on the atmospheric stratification and show that enhanced chromospheric temperatures and cooling rates are associated with strong and inclined magnetic fields that connect patches of opposite magnetic polarity in the photosphere as corroborated by the field extrapolation. The simulation shows that energy dissipation in current sheets during flux emergence leads to a range of observational signatures in the millimeter continuum from compact, transient brightenings to warm fibril-like structures, which is consistent with the observations.

KEYWORDS Sun, chromosphere, active regions, radio, spectropolarimetry, magnetic fields, simulations

Subarcsecond imaging of a solar active region filament with ALMA and IRIS

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An understanding of the processes that lead to the formation of fine threads in filaments or prominences in the solar atmosphere is still elusive. ALMA observations in the millimeter continuum offer a powerful diagnostic of the thermal conditions in filament fine structures. Because of their smaller spatial scales, active region (AR) filaments, in particular, could not previously be resolved in that wavelength range. We present interferometry maps of an AR filament taken with ALMA Bands 6 and 3 with significantly improved spatial resolution (0.6 arcsec at 1.25 mm) compared to previous single-dish observations, and we compare them to ultraviolet imagery provided by IRIS and SDO/AIA and photospheric magnetograms obtained by Hinode/SOT. The 1.25 mm map reveals high-contrast, dark, fine threads co-spatial with the filament body seen in the IRIS Mg II core images and in the AIA 304 passband, but there are significant opacity variations across the filament body on time scales of a few minutes. Surprisingly, the 3 mm maps do not show the same dark/cool structures. In the absence of suitable models in the literature, our results underline the need for follow-up radiative transfer modeling of the radio continuum and the Mg resonance lines to constrain the thermodynamics of AR filaments.

KEYWORDS Sun, chromosphere, filaments, radio, ultraviolet

IAUS 372
#992

Fast Multi-Layer Spectral Inversion of the Hα And Ca II 8542 Line Spectra Using a Deep Neural Network

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Recently a multilayer spectral inversion (MLSI) model has been proposed to infer the physical parameters of plasmas in the solar chromosphere from strong absorption line profiles taken by the Fast Imaging Solar Spectrograph (FISS). We apply a deep neural network (DNN) technique to the MLSI to reduce computational costs. We train the model using pairs of absorption line profiles from FISS and their 13 physical parameters calculated from the MLSI for 49 scan rasters (~ 2,000,000 datasets). We use a fully connected network with skip connections and multi-branch architecture to avoid the problem of vanishing gradients and improve the model's performance. Our test shows that the DNN model successfully reproduces the physical parameter maps of a scan raster observation with high accuracy and a computing time of about 2 seconds, which is about 4300 times faster than the MLSI. We also confirm that the DNN model reliably provides the variation of physical parameters with time. Taking advantage of the high performance of the DNN model, we plan to provide the physical parameter maps from all the FISS observations to understand the chromospheric plasma conditions in various solar features.

KEYWORDS Solar chromosphere, Spectroscopy, Neural Networks

IAUS 372
#903

Understanding Weak Impulsive Narrowband Quiet Sun Emissions (WINQSEs)

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The confluence of the data from the Murchison Widefield Array (MWA) and an imaging pipeline tailored for spectroscopic snapshot images of the Sun at low radio frequencies have led to enormous improvements in the imaging quality of the Sun. Among other science advances, these developments have lowered the detection threshold for weak nonthermal emissions by up to two orders of magnitude as compared to earlier studies, and have enabled our discovery of Weak Impulsive Narrowband Quiet Sun Emissions (WINQSEs). Their typical flux densities lie in the range of a few mSFU (1 SFU = 10,000 Jy) and they are found to occur in large numbers all over the quiet Sun regions. In the solar radio images, they appear as compact sources and our estimate of their median duration is limited by the instrumental resolution of 0.5 s. Their spatial distribution and various other properties are consistent with being the radio signatures of coronal nanoflares hypothesized by Parker (1988) to explain coronal heating in the quiet Sun emissions. As steps towards exploring this tantalising possibility of making progress on the coronal heating problem, we have been pursuing multiple projects to improve our ability to detect and characterise WINQSEs. These include attempts to look for WINQSEs in multiple independent datasets; using different independent detection techniques; attempting to characterise their morphologies in radio maps using Machine Learning based approaches; looking for their counter parts in EUV wavelengths; estimating the energy associated with groups of WINQSEs; and investigation of the spectro-temporal structure of WINQSEs. Here we present the current status of these projects.

KEYWORDS Sun: Corona, Sun: Radio radiation, techniques: interferometric

IAUS 372

#719

Quiet Sun heating using machine learning

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The solar corona consists of a million-degree Kelvin plasma. The ever-existing Quiet Sun, which forms a background over which large, dynamic events occur, is also at a million-degree Kelvin. The energetics and heating of this background must hence be studied well to get to the roots of the coronal heating problem. In this work, we analyze > 300,000 light curves from individual pixels using machine learning-driven by the empirical forward model of Pauluhn and Solanki (2007). The impulsive heating forward model has the flaring frequency, flaring timescale, and power-law slope α as free parameters. Our Convolutional neural network-based inversion scheme can infer these free parameters and their associated uncertainties. We apply this inversion scheme on light curves from each pixel in the 171, 193, and 211 Å first and find impulsive events to be a viable source of generating intensity. These events have a typical time scale of 10-20 minutes and occur at 2-3 events per minute. Furthermore, we find the correlations between free parameters may be explained by the domination of conduction losses and the existence of an energy reservoir. We then apply this scheme on full disc integrated and flux-calibrated light curves from X-ray Solar Monitor onboard Chandrayaan-2. Such an inversion gives us a lower bound of the energy flux in QS resulting from luminosity. We find the X-ray results to consistently follow the trends on moving from cooler to hotter plasma emission, though the smallest of events are noted to be of the order of 1e20 ergs. These findings give us a deeper understanding of the viability of impulsive events in heating the solar corona and the advantages offered by data-driven ML algorithms in accelerating science. Finally, these findings stress the importance of future high spatial resolution and time cadence observations to infer the presence of sub-resolution heating events in the corona

KEYWORDS Sun, Solar Corona, Coronal Heating

Long term evolution of magnetic filed proxies as deduced from Archival data

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The regular observation of the solar magnetic field is available only for about the last five cycles. Thus, to understand the origin of the variation of the solar magnetic field, it is essential to reconstruct the magnetic field for the past cycles, utilizing other data sets. Long-term uniform observations for the past 100 yr as recorded at the Kodaikanal Solar Observatory (KoSO) provide such an opportunity. I will demonstrate some examples of reconstruction of the solar magnetic field using the synoptic observations of the Sun's emission in the Ca II K and Hα lines from KoSO. The reconstruction method is based on the fact that the Ca II K intensity correlates well with the unsigned magnetic flux, while the sign of the flux is derived from the corresponding Hα map that provides the information of the dominant polarities. How these recontructed synoptic maps helps in our understadning of solar dynamo will be highlighted.

KEYWORDS Magnetic field, activity, solar cycle, solar dynamo

IAUS 372

#573

Generation of solar UV and EUV data from Ca II K Images by Deep Learning

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We generate solar UV and EUV data from Ca II K data using a deep learning model. For this, we consider a deep learning method (pix2pixHD) based on conditional Generative Adversarial Networks (cGAN). We use Ca II K 393.3 nm images from the Precision Solar Photometric Telescope at the Rome Observatory and Solar Dynamics Observatory (SDO)/Atmospheric Imaging Assembly (AIA) nine-passband (9.4, 13.1, 17.1, 19.3, 21.1, 30.4, 33.5, 160.0, and 170.0 nm) UV/EUV data. We use data from 2011 January to 2015 June except for June and December for training and the remaining one for test. Our model successfully generates SDO/AIA-like solar UV/EUV images from Ca II K images. The mean correlation coefficient (CC) of intensities between AI-generated and real ones with 4 x 4 binning ranges from 0.79 to 0.95 except 17.1 nm one (0.68). We estimate differential emission measures (DEMs) of several structures (coronal loops in an active region, quiet region, and coronal hole) using two data sets: six-channel SDO/AIA images and the AI-generated EUV images from Ca II ones. The estimated DEMs from both methods are similar to each other, demonstrating that the AI-generated data from Ca II ones are feasible for scientific study.

KEYWORDS Ca II, EUV, SDO, AIA, cGAN, DEM

IAUS 372
#586

Improvements of AI-generated solar farside magnetograms and their applications

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Here, we have greatly improved AI-generated solar farside magnetograms from STEREO Ahead (A) and Behind (B) EUV observations than before. We have modified our previous deep learning model and configuration of input datasets to generate more realistic magnetograms. First our model, which is called pix2pixCC, uses an updated loss function which includes correlation coefficients between the real and generated data. Second, we construct input datasets of our model: solar farside EUV observations together with frontside data pairs of EUV observations and magnetograms. We expect that the frontside data pairs give the model the historic information of magnetic field polarity distributions. Our results show that the present model is much better than our previous model (Jeong et al. 2020, ApJ Letter) in view of several metrics. In addition, the AI-generated farside magnetograms produce consistent polar field strengths and magnetic field polarities with those of nearby frontside SDO/HMI magnetograms for solar cycles 24 and 25. Our AI-generated Solar Farside Magnetograms (AISFMs) are now publicly available at Korean Data Center for SDO. We present several applications and results using AISFMs. We construct synchronic global magnetic field maps with SDO/HMI and AISF magnetograms, and extrapolate solar coronal magnetic fields from them. We show that our results are much more consistent with EUV observations than those of the conventional method in view of solar active regions and open field regions (coronal holes). The results show more consistently the sequences of coronal structure changes over several solar rotation. Finally we suggest several prospects to study global magnetic connectivity with multi-view point observations, e.g., STEREO, Parker Solar Probe, and Solar Orbiter.

KEYWORDS Solar magnetic fields, Multi-view point observations, Solar corona, The Sun, Convolutional neural networks, Deep learning

IAUS 372
#3360

Spectroscopic detection of Alfvénic waves in the chromospheric fibrils of a solar quiet region

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We report observations of transverse magnetohydrodynamic (MHD) waves in fibrils of a quiet Sun region using spectroscopic data. Different from previous studies that measured transversal displacements of fibrils in imaging data, we investigated the line-of-sight (LOS) velocity oscillations of the fibrils in spectral data. The observations were carried out with the Fast Imaging Solar Spectrograph of the 1.6 meter Goode Solar Telescope of the Big Bear Solar Observatory. By using the spectral data of the Hα and Ca II 8542 Å lines, we measured the LOS velocities at two adjacent points along each fibril in a quiet region. In the case of the velocities showing high cross-correlation, we determined as Alfvénic wave packets. From our analysis, we identified numerous Alfvénic wave packets in the quiet Sun fibrils. The dominant periods of the waves are in 3, 5, 10 minute bands. In addition, we statistically investigated their wave properties such as propagation speed, velocity amplitude and propagation direction. We conclude that Alfvénic waves are pervasive in the quiet Sun fibrils.

KEYWORDS Solar atmosphere, Solar chromosphere, Alfvén waves

IAUS 372

#3292

Multi-messenger investigations of a sunspot as a source of slow solar wind

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We present complementary research of the AR 8535 sunspot magnetic field structure and atmosphere. We establish the existence of open field line structures in agreement with EUV observations, identify corresponding solar wind features in near-Earth measurements from the Advanced Composition Explorer (ACE) spacecraft, and construct a sunspot atmosphere model that includes an open field line component and qualitatively reproduces the observed reduced microwave brightness temperature in the northern part of the sunspot in Very Large Array (VLA) observations from 13 May 1999. These investigations motivate further research of similar ARs as sources of slow solar wind using the current state-of-the-art probes Solar Orbiter and Parker Solar Probe and the proposed Frequency Agile Solar Radiotelescope (FASR).

KEYWORDS slow solar wind, Sun: open fields, Sun: microwave emission

IAUS 372

#3229

Synoptic acquisition of full-disk magnetic fields in the photosphere and the chromosphere by an infrared spectro-polarimeter on the Solar Flare Telescope

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The National Astronomical Observatory of Japan (NAOJ) has been running a synoptic acquisition of full-disk magnetic fields in the solar photosphere and the chromosphere with the Solar Flare Telescope (SFT) since 2010. SFT has a 15 cm aperture refractive telescope equipped with an infrared spectro-polarimeter capable of simultaneous observations of Stokes profiles at the Fe I 1 1564.8 nm and Si I 1082.7 nm lines for photospheric vector fields as well as at the He I 1083.0 nm line for chromospheric and filament magnetic fields. The spectro-polarimeter uses two InGaAs detectors, one for the 1564.8 nm line and the other for the 1082.7 and 1083.0 nm lines, with 640 x 512 format as focal-plane cameras which are synchronously read-out triggered by a rotating waveplate with a rotation speed of 4.1 rps. The solar disk is covered by two swaths (the northern and southern hemispheres) of 640 pixels each. The final magnetic field maps are made of 1200 x 1200 pixels with a pixel size of 1''.8. The observations have revealed statistical properties of magnetic fields in dark filaments and solar-cycle dependence of quiet Sun magnetic fields in the photosphere. We are working on improving the calibration of polarimetric data, including correction of detector non-linearity, removal of polarization cross-talks, improvement of waveplate wobbling, and removal of polarization fringes, etc. The knowledge gained through the calibration and processing of the data should be useful for future synoptic observations using an infrared spectro-polarimeter such as ngGONG.

KEYWORDS photosphere, chromosphere, synoptic observation, infrared, spectro-polarimeter

High Resolution Observations of a Plume's Footpoint in Solar Coronal Hole

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Plumes are hazy open structures in coronal holes extending from the solar surface to the corona and are considered a possible source of solar wind. Plumes are thought to be rooted in strong unipolar photospheric flux patches (network/plage region). The magnetic activities at the base of plumes play a crucial role in producing the outflows and propagating disturbances (PDs). However, the role of photospheric/chromospheric activities (e.g., jets/spicules) at the base of plume and its connection to PDs is poorly understood. Using high-resolution observations of a plume on July 23, 2020, from the 1.6 m Goode Solar Telescope (GST), Interface Region Imaging Spectrograph (IRIS), and SDO/AIA, we analyzed chromospheric/transition region activities at the base of the plume and its connection to outflows/PDs in the plume. GST Visual Imaging Spectrograph (VIS) images reveal repetitive spicules with blue-shifted emission (pseudo-Doppler maps) at the plume's footpoint. In addition, the photospheric magnetograms provide the evidence of mixed polarities at the base of the plume. IRIS Mg II h Dopplergrams show strong blue-shifted emission (~50 km/s) and a high brightness temperature region (Mg II k2 line) at the footpoint of the plume. The long period PDs (P~20-25 min) along the plume (AIA 171 Å) match the periodicity of spicules in the chromospheric images; suggesting a close connection between the spicules and PDs. We suggest that the interchange reconnection between close and open flux at the plume's footpoint is the most likely candidate to produce outflow and associated PDs along the plume.

KEYWORDS Sun, Coronal Hole, Plume, Spicules, GST, IRIS, SDO

IAUS 372

#3208

A new mechanism for the butterfly diagram of the solar cycle

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The butterfly diagram of the solar cycle shows the equatorward migration of the emergence latitudes of sunspots as the solar cycle evolves. The equatorward meridional flow at the bottom of the convection zone is believed to be responsible for this migration. However, helioseismological studies indicate controversial forms of the meridional flow, which even presents poleward flow at the bottom. This motivates us to explore a new mechanism for the butterfly diagram. This study aims to demonstrate that the latitude-dependent radial flux transport could cause the butterfly diagram. Using a data-driven Babcock-Leighton-type dynamo model, we carry out simulations to explore how the latitude-dependent radial flux transport, e.g., the latitude-dependent pumping, affects the migration of the toroidal field, under different meridional flows profiles. The results indicate that when the radial transport speed at higher latitudes is larger, the magnetic fields at higher latitudes are transported downward earlier than that at lower latitudes whatever the meridional flow profiles are. Therefore, the bottom toroidal fields at higher latitudes are regenerated earlier than that at lower latitudes. Hence the butterfly-like pattern, which corresponds to the time-latitude evolution of the toroidal field, can be generated.

KEYWORDS Solar cycle, Solar dynamo, Meridional circulation

Power spectra of the sun's large-scale magnetic field during solar cycles 23 and 24

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The magnetic power spectrum analysis provides an effective way to understand the observed distribution of the photospheric magnetic fields and their interaction with plasma motions. Past attempts concentrate on Fourier decomposition of local magnetograms. Here we aim to investigate the power spectra using spherical harmonic decomposition of SOHO/MDI and SDO/HMI synoptic magnetograms for cycles 23 and 24. The power spectra derived from the HMI and MDI radial magnetograms during the period of overlap show the same distribution for l<200 (22 Mm), but the spectral densities from HMI magnetograms is 50% lower than that of MDI magnetograms, which is used for the calibration of MDI data so that it can be consistent with HMI data. We separate each cycle into two parts according to the activity amplitude stronger or weaker than the half cycle amplitudes. The average power spectra for the four parts, i.e., strong/weak phases of cycles 23 and 24, are studied. Two peaks are clearly presented on the four power spectra. They are l=30 and l=120, corresponding to the typical sizes of active regions (146 Mm) and supergranulations (36 Mm), respectively. The slope between the two characteristic scales is about -0.7 during the strong phase of cycle 23. The weaker the solar activity is, the flatter the slope of the power spectrum and the weaker spectral densities are. For l<30 the average power spectra of the four parts show a similar power index, which is 1.2.

KEYWORDS solar magnetic fields, power spectrum, spherical harmonic decomposition

IAUS 372
#3205

Automatic detection of solar active regions from SOHO/MDI and SDO/HMI synoptic magnetograms

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Solar active regions (ARs) play an essential role in solar physics. They not only provide insight into the solar dynamo but also lead to long and short-term solar variability.

In this work, we aim to develop a new method to automatically detect ARs from SOHO/MDI and SDO/HMI synoptic magnetograms and to provide a new database of ARs between 1996 and 2020. The detection method has five modules: (1) adaptive threshold segmentation to remove the background magnetic fields with different thresholds in different pixels; (2) morphological closing operation and opening operation to remove small magnetic segments and get the kernel pixels of ARs, (3) region growing to get single whole ARs, (4) closing operation and removing small decayed ARs segments further; and (5) merging neighbor regions and removing unipolar regions.

Since MDI and HMI synoptic magnetograms have different resolutions, we use the magnetograms during the overlap period to calibrate the parameters used in HMI magnetograms to obtain the same ARs detections as in MDI magnetograms. Thus we obtain the homogenous ARs dataset including location, area, and flux for cycles 23 and 24. The dataset is evaluated by comparing it with other datasets, i.e., sunspot number, NOAA AR number and area, SMARPs and SHARPs number, area and flux, and BARD number, area and flux. Moreover, we find that although cycle 24 is about twice weaker than cycle 23 based on the sunspot number, the numbers and total flux of median and weak ARs in the two cycles are almost the same.

KEYWORDS solar active region, automatic identification, solar cycle

IAUS 372

#3115

Plasmoids, flows, and Jets During Magnetic Reconnection in a Failed Solar Eruption

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We report a detailed analysis of a flare/failed eruption in Active Region 12018 on April 3, 2014, using observations from SDO/AIA, IRIS, STEREO and Hinode/SOT. Initially, we observed multiple jets originating from the cusp of a large coronal bright point (null-point topology) 1-2 hours prior to the slow rise of a filament. The subsequent filament eruption, which was outside the IRIS field of view, was accompanied by a flare but remained confined. Multiple blobs were observed, most likely formed in a breakout current sheet near the cusp during the filament slow rise. During the explosive flare reconnection phase, plasmoids also appeared and moved bidirectionally (speed=100-285 km/s, periodicity~70 s) in the flare current sheet below the erupting filament. The tiny jet-like features in the fan loops were detected during the filament slow-rise/pre-flare phase associated with slow interchange/breakout reconnection at 3D null followed by multiple plasmoids moving along the fan-loops/separatrix. We will discuss why our interpretation is more robust than the nanoflare heating/flows suggested by Antolin et al. (2021).

KEYWORDS

IAUS 372

#3065

The Effect of the Chromospheric Temperature on Coronal Heating

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Recent observational and numerical studies show a variety of thermal structures in the solar chromosphere. Given that the thermal interplay across the transition region is a key to coronal heating, it is worth investigating how different thermal structures of the chromosphere yield different coronal properties. In this work, through the MHD simulation of coronal loops, we study how the coronal properties are affected by the chromospheric temperature. When the temperature in the underlying chromosphere is higher, because the chromosphere extends to a larger height, the coronal part of the magnetic loop becomes shorter, which enhances the conductive cooling. A larger loop length is then required to maintain the hot corona against the thermal conduction. From our numerical simulations, we derive a condition for the coronal formation with respect to the half loop length l_loop in a simple form: l_ loop > αT_min + l_th, where T_min is the minimum temperature in the atmosphere and parameters α and l_th have negative dependencies on the coronal field strength. Our conclusion is that the chromospheric temperature has a non-negligible impact on coronal heating for loops with small length and weak coronal field. In particular, the enhanced chromospheric heating could prevent the formation of the corona.

KEYWORDS corona, chromosphere, MHD

e-Talks

IAUS 372

#2872

Effect of Coronal rain on oscillation properties of Coronal loops

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Active region Coronal loops are frequently subjected to footpoint heating which initiates thermal instability in the corona leading to plasma condensation in the time scale of minutes, hence forming the coronal rain. Transverse oscillations of coronal loops triggered by coronal rain are observed, but the change in their oscillation properties due to coronal rain is not yet confirmed. We present the analysis of an event of coronal rain simultaneously observed by Interface Region Imaging Spectrograph (IRIS) and Atmospheric Imaging Assembly (AIA). The oscillation properties of the coronal loop are investigated before and after the formation of coronal rain. We found an increase in the period and amplitude of oscillations during coronal rain for a few instances. The amplitude of oscillation captured by AIA 171 channel, before and after coronal rain, is in the range of 50 to 200 Km, and in Optically thick channels, during coronal rain, is in the range of 100 to 400 Km, whereas the period of oscillation, before and after coronal rain, is in the range of 1 to 3 min and during coronal rain, it is in the range of 1 to 5 min. The increase in the period can be due to density enhancement at the loop top as in the long-wavelength limit; the period will be directly proportional to loop density. The observed emission of loop apex in individual SDO/AIA and IRIS/SJI bandpasses showed the cooling of loop top material and can be linked with the appearance of oscillations in distance-time maps.

KEYWORDS Sun, Oscillations, Coronal loops

IAUS 372

#2850

Signature of tilt quenching from observation of tilted bipolar magnetic regions on the Sun

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The tilt of the bipolar magnetic region (BMR) is crucial in the Babcock–Leighton process for the generation of the poloidal magnetic field in the Sun. Based on the thin flux-tube model of the BMR formation, the tilt is believed to be caused by the Coriolis force acting on the rising flux tube of the strong toroidal magnetic field from the base of the convection zone. We analyze the magnetic field dependence of BMR tilts using the magnetograms of the Michelson Doppler Imager (1996–2011) and Helioseismic and Magnetic Imager (2010–2018). We observe that the distribution of the maximum magnetic field (Bmax) of BMRs is bimodal. Its first peak at the low field corresponds to BMRs that do not have sunspots as counterparts in the white-light images, whereas the second peak corresponds to sunspots as recorded in both types of images. We find that the slope of Joy's law (γ0) initially increases slowly with the increase of Bmax. However, when Bmax 2 kG, γ0 decreases. The Scatter of the BMR tilt around Joy's law systematically decreases with the increase of Bmax. The decrease of observed γ0 with Bmax provides a hint to a nonlinear tilt quenching in the Babcock–Leighton process. We finally discuss how our results may be used to make a connection with the thin flux-tube model.

KEYWORDS Solar active regions, Solar activity, Solar cycle, Bipolar sunspot groups

IAUS 372
#2449

MAGNETOSEISMOLOGY FOR THE SOLAR CORONA: FROM ~10 GAUSS TO CORONAL MAGNETOGRAMS

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Magnetoseismology, a technique of magnetic field diagnostics based on observations of magnetohydrodynamic (MHD) waves, has been widely used to estimate the field strengths of oscillating structures in the solar corona. However, previously magnetoseismology was mostly applied to occasionally occurring oscillation events, providing an estimate of only the average field strength or one-dimensional distribution of field strength along an oscillating structure. This restriction could be eliminated if we apply magnetoseismology to the pervasive propagating transverse MHD waves discovered with the Coronal Multi-channel Polarimeter (CoMP). Using several CoMP observations of the Fe XIII 1074.7 nm and 1079.8 nm spectral lines, we obtained maps of the plasma density and wave phase speed in the corona, which allow us to map both the strength and direction of the coronal magnetic field in the plane of sky. We also examined distributions of the electron density and magnetic field strength, and compared their variations with height in the quiet Sun and active regions. Such measurements could provide critical information to advance our understanding of the Sun's magnetism and the magnetic coupling of the whole solar atmosphere.

KEYWORDS solar corona, coronal magnetic field, MHD waves

IAUS 372

#2385

An automatic algorithm to track bipolar magnetic regions in magnetograms to study the evolution of their properties

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The bipolar magnetic regions (BMRs) acts as proxies of intense solar photospheric magnetic field. Properties of BMR, particularly, the tilt angle play a critical role in generating the observed polar magnetic field and its reversal. Hence, a long-term study of BMR over its lifetime is crucial not only to understand the solar dynamo but also to identify the origin of the properties of BMR. In our work, we have developed an automatic algorithm to detect and track the BMRs from the line-of-sight magnetograms of MDI (1996-2012) and HMI (2012-2021) over their lifetime/disk passage. Our algorithm provides information about various properties of BMRs, such as tilt, lifetime, area, position and magnetic properties. Unlike the already existing data products of tracked active region information, our algorithm provides a homogeneous dataset with all the information of tracked BMRs from 1996. Also, our algorithm can be implemented on any available magnetograms. Here, we present the details of our algorithm and the features of BMR, particularly the tilt angle, magnetic field strength and lifetime.

KEYWORDS Sunspot, Solar Cycle, Magnetic Field, Solar Dynamo, Solar Instrumentation

IAUS 372

#2255

Plasma flows in the active-region as seen by IRIS

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We have utilized the spectroscopic observations (e.g., Mg II k 2796.35 Å, Mg II h 2803.52 Å, C II 1334.53 Å, Si IV 1402.77 Å, and O IV 1401.52 Å) from the Interface-region Imaging Spectrograph (IRIS) to diagnose the plasma flows of an active-region (AR). We have investigated the Doppler velocity profile, i.e., Doppler velocities versus the formation temperature of selected spectral lines. We have chosen many locations within the AR, and performed the statistical diagnostics of Doppler velocity profiles. It is found that transitions-region lines (i.e., Si IV 1402.77 Å, and O IV 1401.5 Å) have maximum Doppler velocity while the chromospheric lines (i.e., Mg II k 2796.35 Å and Mg II h 2803.52 Å) have the least Doppler velocity. However, the CII 1334.53 Å line shows the intermediate values of Doppler velocity. Hence, we can conclude that redshift decreases as we go from the transition-region to the chromosphere, and it is consistent with the Parker's Nanoflare theory.

KEYWORDS Spectral lines, Active Regions, Plasma Flows, Chromosphere, Transition Region

IAUS 372
#2072

Investigating small scale brightening events and the impact of angular resolution of solar ALMA observations

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An algorithm was developed to automatically detect brightening events in solar ALMA data and determine their lifetimes, sizes and velocities. The intensities of the millimeter wavelength radiation is closely linked to the local plasma temperature, which enables to study the potential heating of the chromosphere in connection to the events. However, the brightening events are of comparable scales as the angular resolution of solar ALMA observations and their magnitudes are significantly degraded.

The instrumental limitations were estimated by performing simulated solar ALMA observations which then were applied on millimeter wavelength observables calculated from 3D radiation-MHD Bifrost models in order to acquire the magnitude of the degradation and correction factors that could be applied to observational data. The correction factors provides more accurate values of the magnitudes of the brightening events which is imperative when deriving the transport of energy and the potential contribution to the heating of the chromosphere by propagating shock waves.

In addition, the height of formation of the millimeter wavelength radiation is strongly connected to the small scale dynamics and varies from low chromosphere to the transition region. The radiation formation height was studied in connection to specific brightening events and estimations on the formation heights across the field of view of observational data were acquired by statistical correlation to the small scale dynamics.

These estimations and improved methodologies of analysis help to perform meaningful interpretation of solar ALMA data, that can provide estimations on the potential heating by shock waves at different layers in the solar atmosphere.

KEYWORDS Chromosphere, interferometry, ALMA, shock, waves, heating, simulations

IAUS 372
#1402

Eruption of the EUV Hot Channel from the Solar Limb and Associated Moving Type IV Radio Burst

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Using the observations from the Solar Dynamics Observatory, we study an eruption of a hot-channel flux rope (FR) near the solar limb on 2015 February 9. The pre-eruptive structure is visible mainly in EUV 131 Å images, with two highly sheared loop structures. They undergo a slow rising motion and then reconnect to form an eruptive hot channel, as in the tether-cutting reconnection model. The J-shaped flare ribbons trace the footpoint of the FR that is identified as the hot channel. Initially, the hot channel is observed to rise slowly at 40 km s–1, followed by an exponential rise from 22:55 UT at a coronal height of 87+/-2 Mm. Following the onset of the eruption at 23:00 UT, the flare reconnection then adds to the acceleration process of the coronal mass ejection (CME) within 3 $R_\odot$. Later on, the CME continues to accelerate at 8 m s–2 during its propagation period. Further, the eruption also launched type II radio bursts, which were followed by type III and type IVm radio bursts. The start and end times of the type IVm burst correspond to the CME's core height of 1.5 and 6.1 $R_\odot$, respectively. Also, the spectral index is negative, suggesting that nonthermal electrons are trapped in the closed loop structure. Accompanied by this type IVm burst, this event is unique in the sense that the flare ribbons are very clearly observed together with the erupting hot channel, which strongly suggests that the hooked parts of the J-shaped flare ribbons outline the boundary of the erupting FR.

KEYWORDS solar prominences, solar radio emission, solar coronal mass ejections, solar magnetic reconnection

IAUS 372

#632

Study of Ionospheric behaviour during the intense geomagnetic storms in 24th solar cycle over different Latitudes and Longitudes

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One of the most important scientific goals in solar physics is to understand how the interplay between the Sun, the space weather that creates storms, and the impacts on the Earth are all related to each other. The ionospheric perturbations during intense geomagnetic storms caused the disturbance in the earth's magnetic field. A geomagnetic storm leads to a number of disruptions in technological applications such as space vehicle operation, interrupted radio communication, and disrupted power grids. The devastating effects of such events could easily cause trillions of dollars in damage. The responses of these selected storms to the ionosphere have been investigated around the globe. In this paper, we have studied the behaviour of the Ionospheric Total Electron Content (TEC) in both hemispheres (Northern and Southern) in the 00–3600 longitude ranges during the 24th solar cycle over different geographic latitudinal and longitudinal stations using data recorded from geomagnetic observatories for extreme storm investigations. The analysis has been done in this paper provides a detailed summary of the nature and extent of the latitudinal ionospheric irregularities.

KEYWORDS Space Weather, Geomagnetic Storm, Total Electron Content, Ionospheric Irregularities

IAUS 372
#2952

Sun-as-a-star spectroscopic observations of the line-of-sight velocity of a solar eruption on October 28, 2021

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The propagation direction and true velocity of a solar coronal mass ejection, which are among the most decisive factors for its geo-effectiveness, are difficult to determine through single-perspective imaging observations. Here we show that Sun-as-a-star spectroscopic observations, together with imaging observations, could allow us to solve this problem. Using observations of the Extreme-ultraviolet Variability Experiment onboard the Solar Dynamics Observatory, we found clear blue-shifted secondary emission components in extreme ultraviolet spectral lines during a solar eruption on October 28, 2021. From simultaneous imaging observations, we found that the secondary components are caused by a mass ejection from the flare site. We estimated the line-of-sight (LOS) velocity of the ejecta from both the double Gaussian fitting method and the red-blue asymmetry analysis. The results of both methods agree well with each other, giving an average LOS velocity of the plasma of ~423 km/s. From the 304 angstrom image series taken by the Extreme Ultraviolet Imager onboard the Solar Terrestrial Relation Observatory-A (STEREO-A) spacecraft, we estimated the plane-of-sky (POS) velocity from the STEREO-A viewpoint to be around 587 km/s. The full velocity of the bulk motion of the ejecta was then computed by combining the imaging and spectroscopic observations, which turns out to be around 596 km/s with an angle of 42.4 degrees to the west of the Sun-Earth line and 16.0 degrees south to the ecliptic plane.

KEYWORDS coronal mass ejection, spectroscopy, filament eruption

IAUS 372
#2935

Investigation of coronal mass ejection at different heliospheric distances using Solar Orbiter, BepiColombo, and Wind data

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This paper addresses the investigation of the ICMEs encountered by Solar Orbiter, BepiColombo and Wind spacecrafts on April 19-20, 2020, from both an observational and a modeling perspective. A coronal mass ejection (CME) was observed in situ by Solar Orbiter on April 19, 2020, at a heliocentric distance of nearly 0.8 AU. The CME was later detected in situ by the Wind and BepiColombo spacecrafts on April 20, while BepiColombo was quite near to Earth. Because the spacecraft were separated by less than 5° in longitude, this CME gives an excellent opportunity for a triple radial alignment investigation. The CME, which was initiated on April 15, was caused by an almost completely isolated streamer explosion. The event was remotely detected by the Solar Terrestrial Relations Observatory (STEREO)-A satellite from 75 degree longitudenal angle, which is an extremely well-suited perspective for heliospheric observing filed of view of an Earth-directed CME. The four spacecraft's configuration provided an extraordinarily significant relationship between global imaging and in-situ investigations of the CME. To estimate the global structure of the CME and its evolution as it travelled through the inner heliosphere, we employed in situ measurements from Solar Orbiter, Wind, and BepiColombo, as well as distant observations from STEREO-A. When examination of magnetic field strength relationships indicates that the CME expansion is unlikely to be self-similar or cylindrically symmetric. Additionally, we compare in situ magnetic field measurements from distinct spacecraft, we observe that the influence of the highest magnetic field strength on heliocentric distance reduces.

KEYWORDS Coronal Mass Ejection, Solar Orbiter, BepiColombo

IAUS 373

Resolving the Rise and Fall of Star Formation in Galaxies

Invited & Contributed Talks

IAUS 373
#3016

The local and global relations between Σ*, Σ SFR and Σ mol that regulate star-formation

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We present a new characterization of the relations between star-formation rate, stellar mass and molecular gas mass surface densities at different spatial scales across galaxies (from galaxy wide to kpc-scales). To do so we make use of the largest sample combining spatially- resolved spectroscopic information with CO observations, provided by the EDGE-CALIFA survey, together with new single dish CO observations obtained by APEX. We show that those relations are the same at the different explored scales, sharing the same distributions for the explored data, with similar slope, intercept and scatter (when characterized by a simple power-law). From this analysis, we propose that these relations are the projection of a single relation between the three properties that follows a distribution well described by a line in the three-dimension parameter space. Finally, we show that observed secondary relations between the residuals and the considered parameters are fully explained by the correlation between the uncertainties, and therefore have no physical origin. We discuss these results in the context of the hypothesis of self-regulation of the star-formation process.

KEYWORDS starformation, scaling relation, galaxy evolution

IAUS 373

#2621

Supernova-Driven Star Formation in the Milky Way

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Understanding the role of supernova feedback in the production of dense molecular gas is key for understanding the self-regulation of star formation in galaxies. However detailed observational constraints on supernova-driven star formation in the Milky Way have remained elusive, largely due to low resolution models of our local interstellar medium. In this talk, I will discuss how new 3D spatial and dynamical constraints from Gaia have revealed "positive" supernova feedback at work in the solar neighborhood. In particular, I will show how essentially all nearby star-forming complexes lie on the surface of the Local Bubble, and that their young stars show outward expansion perpendicular to the bubble's surface. Using these young stars' motions to reconstruct the star formation history of our solar neighborhood, I will explain how a set of supernova explosions beginning 14 Myr ago powered the expansion of the Local Bubble. This expansion swept up the ambient interstellar medium into an extended shell that has now fragmented and collapsed into the most prominent nearby star-forming complexes. I will conclude by discussing the relationship between the Local Bubble and nearby spiral structure, which together provide new context for understanding triggered star formation in the larger galactic ecosystem.

KEYWORDS star formation, supernova feedback, molecular clouds

IAUS 373
#2624

ALMA resolved views of molecular filaments/clumps in the Large Magellanic Cloud: A possible gas flow penetrating one of the most massive protocluster systems in the Local Group

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We present spatially resolved molecular filaments in the high-mass star-forming regions N159E-Papillon, W-South, and W-North in the Large Magellanic cloud (LMC). Our ALMA observations in CO isotopes revealed remarkable hub-filament systems with a typical width of 0.1 pc in 13CO, where a young HII region (the Papillon Nebula) and an embedded high-mass protostar along with six protostellar outflows have been newly discovered/resolved (Fukui+19; Tokuda+19). All these young protostellar objects have an age of 10^4 to 10^5 yrs, whereas they are scattered over a distance spanning ~50 pc.

The most massive clump in the observed regions, N159W-North MMS-2, shows especially massive/dense nature whose total H_2 mass and peak column density are ~10^M_sun and ~10^24 cm^-2, respectively, and harbors massive (~100 M_sun) starless core candidates identified as its internal substructures (Tokuda+22 sbumitted). The CO (1-0) data set with a larger field of view reveals a conical-shaped, ~30 pc long complex extending toward the northern direction. These features indicate that a large-scale gas compression event may have produced the massive star-forming complex. Based on the striking similarity between the N159W-North complex and the other two regions, we propose a teardrops inflow model that explains the synchronized, extreme star formation across ~50 pc, including one of the most massive protocluster clumps in the Local Group. The proposed flow, driven by the tidal interaction between the LMC and SMC (e.g., Fukui+17), explains the formation of the hub-multi-filament system as shown by recent MHD simulations (Inoue+18), which predict the synchronized triggered formation of the most massive star at the hub and additional star formation along the dense filaments/clumps.

KEYWORDS ISM, clouds, high-mass star formation, protostars, Magellanic Clouds

IAUS 373
#2808

Turbulence-Controlled Hierarchical Star Formation in the Large Magellanic Cloud

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We perform a statistical clustering analysis of upper main-sequence stars in the Large Magellanic Cloud (LMC) using data from the Visible and Infrared Survey Telescope for Astronomy survey of the Magellanic Clouds. We map over 2500 young stellar structures at 15 significance levels across ~120 square degrees centred on the LMC. The structures have sizes ranging from a few parsecs to over 1 kpc. We find that the young structures follow power-law size and mass distributions. From the perimeter-area relation, we derive a perimeter-area dimension of 1.44±0.20. From the mass-size relation and the size distribution, we derive two-dimensional fractal dimensions of 1.50±0.10 and 1.61±0.20, respectively. We find that the surface density distribution is well-represented by a lognormal distribution. We apply the Larson relation to estimate the velocity dispersions and crossing times of these structures.Our results indicate that the fractal nature of the young stellar structures has been inherited from the gas clouds from which they form and that this architecture is generated by supersonic turbulence. Our results also suggest that star formation in the LMC is scale-free from 10 pc to 700 pc.

KEYWORDS stars: early type, methods: statistical, stars: formation, Large Magellanic Cloud, galaxies: structure

IAUS 373
#1877

Abundant Molecular Cloud Cores with Photo-Dissociated Envelopes Discovered in the XUV Disk of M83 with ALMA

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The GALEX UV satellite discovered numerous massive stars beyond the optical edges of galactic disks (extended UV disks, or XUV disks). Scores of observations searched for their parental molecular clouds, but they resulted largely in non-detection using CO(J=1-0) or CO(2-1). Only a few detections so far do not account for the ubiquity of the outer disk massive star formation, raising a question as to whether the conditions of star formation are different there. We report the first and surprising detections of 23 dense molecular cloud cores via CO(J=3-2) emission in the XUV disk of the spiral galaxy M83 with ALMA. The brightest clump shows the CO(J=3-2)-traced mass and star formation activity surprisingly similar to those of local MW molecular clouds, such as the Orion A cloud with Orion Nebula. The newly detected clouds likely have CO-deficient, albeit H2-rich, thick outer layers due to the selective photo-dissociation in the low metallicity outer disk, explaining their faintness in CO(1-0) or CO(2-1). However, their dense cores reside at the hearts of the clouds, being protected from the photo-dissociation, remaining bright in CO(3-2), and likely forming the massive stars in the XUV disk. Besides the presence/absence of CO in the H2-rich envelope, this core-envelope mass structure is apparently universal among molecular clouds in the MW and XUV disks. If it is also universal at high redshifts, it would justify the use of mid-J CO transitions for measurements of ISM masses in distant galaxies.

KEYWORDS star formation, molecular clouds, local spiral galaxy, XUV disk, detections of many molecular clouds, universal cloud structure

IAUS 373
#2190

A sub-grid model for the molecular cloud lifecycle

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The lifecycle of giant molecular clouds (GMCs) - the sites of star formation in galaxies - is unresolved at the resolution of cosmological volume simulations. Modelling the star formation cycle in these simulations, which is necessary to correctly model the physics of galaxy formation and evolution, therefore requires a sub-grid model for cloud formation, evolution and destruction.

Here we present such a sub-grid model for the molecular cloud lifecycle, based on the excursion sets formalism first introduced by Hopkins 2012. The model is simple, depending only on large-scale properties of the galactic environment, which are resolved in cosmological simulations. It includes the influence of gas self-gravity, turbulence, and large-scale galactic dynamics. We compare our model predictions to high-resolution (2-6 pc) Arepo simulations of GMC populations in isolated galaxies spanning the galactic main sequence, including a Milky Way analogue, an NGC300 analogue, and analogues of Early-Type galaxies. We find that the sub-grid model is able to reproduce the rate of cloud formation, initial cloud mass spectrum, and cloud mass accretion of the GMC population in the high-resolution simulations, along with the galaxy-scale Kennicutt-Schmidt relation.

KEYWORDS Star formation, Galaxy evolution, Sub-grid models, Numerical simulations, Giant molecular clouds

IAUS 373
#702

Molecular Gas Contents and Star Formation Efficiency in Local Galaxies

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Distribution, contents, dynamical environments, and physical conditions of molecular gas and their relations with global star formation is a clue to understand galaxy evolution. Many CO observations for galaxies including single-pointing, scan observations, or two-dimensional mappings so far have given us some fundamental relations between molecular gas contents and star formation in galaxies. However, it is still unclear why star formation efficiency (SFE) is not universal among galaxies or within a galaxy. The goal of this work is to make clear molecular gas contents in local galaxies and the cause of variety in SFE. We conducted a CO mapping for local galaxies, "CO Multi-line Imaging of Nearby Galaxies (COMING)" and expanded it, which gives us data cubes of more than 150 galaxies in 12CO, 13CO and C18O J=1-0 lines with a spatial resolution of several 100 pc to a few kpc. The total molecular gas mass derived using the standard CO-to-H2 conversion factor correlates with the total stellar mass. SFE, which is derived from GALEX FUV and/or WISE data, averaged over galactic structures such as spiral arms, bar, and bar ends correlates with molecular gas density. The density increases with velocity dispersion of molecular gas, while it decreases where the velocity dispersion exceeds about 100 km s-1. The intensity ratio of 12CO to 13CO differs among galactic structures and it reflects molecular gas properties as previous works have shown. However, decomposing molecular gas into cloud-phase component and diffuse one based on detection of 13CO emission gives us more meaningful information. SFE for cloud-phase molecular gas is not so different among galactic structures, therefore, the difference of SFE is caused by the proportion of cloud-phase gas to the total molecular gas. Therefore, the variation of SFE seen among galaxies and within a galaxy is explained by molecular gas dynamics and resultant variation of the proportion of diffuse and cloud-phase molecular gas.

KEYWORDS local galaxies, molecular gas, carbon monoxide, star formation

IAUS 373
#2866

The link between cold gas global reservoirs and star-formation activity in galaxies

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Understanding how galaxies form and evolve requires knowledge of their cold gas component, and how this depends on their structural and star formation properties, as well as large-scale environment. Significant effort has gone into systematic surveys of cold gas in the local Universe, resulting in a network of scaling relations that connect atomic and molecular gas content of galaxies to their global properties and environments. I will talk about lessons learned from cold gas surveys of nearby galaxies and discuss how the next-generation cold gas surveys will soon allow us to make further progress in this area.

KEYWORDS galaxies, interstellar medium, star formation

IAUS 373
#1138

First results from the MHONGOOSE ultra-deep MeerKAT HI survey of nearby galaxies

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I present first results from the ongoing 1650 hours MHONGOOSE neutral hydrogen survey (the MeerKAT Large Survey Project on nearby galaxies). This survey is observing the neutral hydrogen in 30 nearby disk and dwarf galaxies with the MeerKAT radio synthesis telescope in South Africa. The observations reach unprecedented column densities two orders of magnitude lower than those typically observed in galaxy disks. One of the main goals of the survey is the detection of signs of cold gas accretion in these galaxies. A number of galaxies have now been observed to full depth, routinely reaching column densities around ~10^18 cm^-2 at sub-kpc resolution. We find a large variety of low-column density features in and around these galaxies, including low-column density clouds, signs of interaction with low-mass dwarf galaxies, and complex distributions of extra-planar gas near the target galaxies.I give an overview of these results and discuss some of the prospects for the full survey as well as for future SKA observations.

KEYWORDS neutral hydrogen, galaxy evolution, accretion, nearby galaxies

IAUS 373
#1479

Probing the Conditions for the Atomic-to-Molecular Transition in the Interstellar Medium

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Molecular clouds, the principal stellar nurseries, form out of the surrounding diffuse gas through the conversion of atomic (HI) to molecular hydrogen (H2). Among two main flavors of HI (cold and warm neutral medium; CNM and WNM), the colder and denser CNM is expected to be more critical for the conversion, and yet its exact roles remain largely unknown due to difficulty in direct measurements. To overcome this observational challenge and provide unique insights into the roles of the CNM in the formation of molecular gas, we obtained Arecibo HI emission and absorption spectra toward 58 lines of sight probing three molecular clouds in the solar neighborhood (Taurus, Perseus, and California) and analyzed them along with TRAO/PMO 12CO(1-0) emission spectra. Our analyses show that the velocity difference between the CNM and CO is on average a factor of three smaller than that between the WNM and CO (0.6 km/s vs. 1.7 km/s), implying a close spatial association between the CNM and CO. In addition, we found that the CNM becomes colder (spin temperature of 46 K) and more abundant (CNM-to-total HI column density of 0.6) as it gets closer to CO. In other words, the formation of molecular gas is favored in environments where more CNM exists, suggesting that producing the CNM is a key step in the HI-to-H2 transition. Finally, we compared the observed CNM properties to the theoretical model by Bialy & Sternberg (2016), where the structure of the HI-to-H2 transition is controlled by the UV radiation field, metallicity, and density. Our comparison shows that the range of the observed CNM column densities cannot be solely explained by the variation in gas density and hence the simple steady-state chemical equilibrium model by Bialy & Sternberg (2016) may require additional process(s) for the HI-to-H2 transition (e.g., turbulence).

KEYWORDS molecular clouds, interstellar medium, radio lines

IAUS 373

#467

Gas-Star Formation Cycle in Nearby Galaxies

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Star formation, from cold giant molecular clouds to diverse population of stars, is a complex process involving a wide variety of factors and physical processes. In this work, we constrain the link between the gas-star formation cycle and several secular and environmental probe of galaxies. Specifically, we quantify the spatial correlation between molecular gas and star-forming regions for ~ 50 nearby galaxies using the ALMA and narrowband-Hα imaging from the Physics at High Angular resolution in Nearby GalaxieS (PHANGS) survey. At the resolution (150 pc) at which the individual molecular clouds and star-forming regions can be identified, we find that molecular clouds and star-forming regions do not necessarily coexist. The decoupled giant molecular gas and star-forming regions are a signature of evolutionary cycling and feedback of the star formation process. Moreover, our results also show that the lifetime of giant molecular clouds and the evolution of star formation process are not universal but varies among the physical properties and dynamics of their host galaxies. Therefore, the impact of galactic-scale conditions and environments must be considered for a complete understanding of how stars form in galaxies and how this process influences the evolution of the host galaxies.

KEYWORDS Galaxies, Interstellar Medium, Star Formation, Multi-wavelength Survey

IAUS 373

#472

A Search for correlations between turbulence and star formation in LITTLE THINGS and THINGS galaxies

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Local generation of turbulence by star formation is studied in 41 LITTLE THINGS dwarf and BCD galaxies and 11 THINGS galaxies by comparing the kinetic energy density (KED), velocity dispersion (Vdisp), and surface density for HI (ΣHI) with the star formation rate density (SFRD) from GALEX images. Patchy regions with high SFRD in the dwarfs do not usually have high KEDs; a cross correlation between the two shows little correspondence. The excesses in the KED, Vdisp, and ΣHI are also compared with the excess SFRDs on a pixel-by-pixel basis, where excess is determined from the difference between the observed local value and the azimuthal average. The results agree with the cross correlation: there is no significant excess of turbulence in regions of excess SFRD. For THINGS galaxies, the excess Vdisp actually decreases a little in regions of excess SFRD, suggesting that HI cools before star formation begins with no clear evidence for heating immediately afterwards. Most likely, feedback from star formation disrupts molecular clouds and dissipates energy rapidly in high-density gas. Some energy could also be distributed indirectly over larger regions and for longer times.

KEYWORDS feedback, turbulence, kinetic energy density, star formation

IAUS 373
#1881

The impact of ICM ram pressure on the cool gas content and SF activity of galaxies

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The cluster environment can make a strong influence on galaxy evolution. In particular, the ram pressure caused by the presence of an intracluster medium (ICM) is predicted to play a pivotal role in driving galaxies to evolve passively by removing the interstellar medium (ISM) in a relatively short time. The impact of ram pressure on star-forming cool gas has been observed through various gas tracers. In the case of neutral atomic hydrogen (HI) gas, which is generally diffuse and widely distributed including outside the stellar disk of galaxies, it provides a useful tool to identify a range of ram pressure strengths and the relevant ISM stripping stages. In the case of molecular gas which is relatively dense and mostly bound to the inside of the stellar disk, the impact of ICM ram pressure is not as obvious as in the atomic gas. However, radio imaging data clearly reveal the evidence that molecular gas is essentially affected by ram pressure in a similar way as atomic gas. In this talk, I will discuss how the resolved radio data of different cool gas tracers can be reconciled to better understand the impact of ICM ram pressure on the multiphase ISM and how it leads to sustaining and quenching of star formation in galaxies.

KEYWORDS ICM, ram pressure, ISM, star formation, galaxy evolution

IAUS 373
#2886

Dense molecular gas tracers in nearby galaxies

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Both Galactic and extragalactic studies suggest that stars form directly from dense molecular gas. To trace such high volume density gas, HCN and HCO+ J=1 have been widely used for their high dipole moments, relatively high abundances, and intensities. However, the J=1-0 transition of HCN and HCO+ could be arguably dominated by gas components with low volume densities. The higher-J transitions of HCN and HCO+, stand out to better trace the dense gas component directly involved with star formation, despite issues of excitation, astrochemistry, elemental abundance, and radiative transfer. Here we will present high-J HCN/HCO+ observations of nearby star-forming galaxies with APEX and JCMT. We find that the correlations of surface densities of infrared luminosity and dense gas emission, normalised with the area of radio/sub-millimeter continuum, have tighter relations than those of luminosity correlations. On the other hand, ultra-luminous infrared galaxies with active galactic nucleus may also systematically lay above the correlations, indicating potential biases in star formation rates introduced by AGNs.

KEYWORDS

IAUS 373
#451

Molecular Cloud Populations in the Context of Their Host Galaxies: Insights from PHANGS-ALMA

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Molecular clouds are the building blocks of the cold interstellar medium and the immediate sights of star formation in galaxies. Systematic surveys of molecular clouds covering large galaxy samples have been challenging due to the stringent requirements on data resolution, sensitivity, and field of view. I will present my latest research based on PHANGS-ALMA, an ALMA large program mapping the molecular cloud populations in 90 nearby galaxies at ~1" (~50-150 pc) resolution. Combining PHANGS-ALMA with multiwavelength ancillary data, we furnish a multifaceted portrait for the molecular clouds and their kpc-scale environments in star-forming galaxies at z~0. We find ubiquitous correlations between various cloud properties (e.g., mass, surface density, velocity dispersion) and host galaxy local/global properties (e.g., gas, stellar mass, and SFR distributions, as well as orbital kinematics). A variable selection analysis suggests that most of these correlations are mediated by just a few variables, including the kpc-scale molecular gas and SFR surface densities. We also estimate a number of characteristic timescales relevant to molecular cloud evolution and star formation, including the cloud free-fall time and molecular gas depletion time. With these measurements, we test turbulence-regulated star formation models and find the observations in tension with models assuming a pure log-normal density distribution. This project will lead to the public release of a rich multiwavelength database synthesizing key measurements from the PHANGS surveys.

KEYWORDS interstellar medium, star formation, molecular gas, PHANGS survey, ALMA, nearby galaxies, multiwavelength database

IAUS 373
#744

Exploring the evolution of giant molecular clouds in one of the nearest spiral galaxies M33

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The understanding of the evolution of giant molecular clouds (GMCs), which are the main sites of star formation, is essential for unraveling how stars form and how galaxies evolve. There are large variations in star formation activity between GMCs; e.g., the association with star clusters and/or HII regions. Fukui+99 and Kawamura+09 reported that the GMCs are classified into three types according to activities of high-mass star formation: Type I shows no signature of high-mass star formation; Type II is associated with only HII region(s); and Type III with both HII region(s) and young stellar cluster(s). They suggested that this classification indicates the evolutionary stages of GMCs. However, it is difficult to know information on star clusters in external galaxies farther than Local group ones due to the limitation of the spatial resolution.

In order to study the evolution of GMCs in more galaxies, we suggest the new type classification of GMCs using only Ha luminosity, L(Ha); Type I: associated with no HII regions, Type II: associated with HII regions of L(Ha) < 10^37.5 erg/s, Type III: associated with HII regions of L(Ha) > 10^37.5 erg/s. We applied this classification to the M33 CO data, which covers most of the molecular-gas disk at 39 pc resolution, obtained by ALMA 7m array (ACA) combined with IRAM 30m. This spatial resolution is the highest in the studies of GMC evolution in M33. We identified 736 GMCs using PYCPROPS algorithms and classified the GMCs into these three types. Comparing the physical properties of each GMC Type, we found that the values of mass, size, and velocity dispersion slightly increase in the order of Type I, II, and III. Type I GMCs are distributed both in the spiral arm and the inter-arm, whereas most of Type III GMCs exist in the spiral arm. This suggests that the spiral arm plays a vital role in the onset of high-mass star formation. Assuming that the star formation proceeds steadily in time, the timescale of each GMC Type is proportional to the number of them. We roughly estimated the timescale of Type I, II, and III GMCs to be 7 Myr, 13 Myr, and 10 Myr, respectively. This estimate yields the total GMC lifetime of 30 Myr, consistent with that derived by Kawamura+09.

KEYWORDS molecular cloud, star formation, M33, spiral galaxy

IAUS 373
#834

Conditioning star formation in intergalactic clouds

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In various astrophysical objects and under different local conditions gas clouds are observed separated from galaxies in the intergalactic space. Their observational detection differs according to their occurrence. Infalling high-velocity clouds (HVCs) were at first directly observed in 21cm surveys of our Milky Way. Surprisingly, they contain "normal" gas phases of an interstellar medium within gas-rich galaxies, but are void of star formation. Blind surveys of intergalactic HI also discover star-less clouds, while for a few star formation could be verified. More diverse seems the picture of ram-pressure stripped (RPS) clouds of galaxies moving through the hot intra-cluster medium of galaxy clusters. While the stripped-off gas is mostly visible in Halpha only, frequent cases exist for which UV detections reflect embedded star formation also.

Which physical state, as e.g. cloud mass, external heating, etc., is conditioning star formation in these clouds or suppressing it, is the objective of our presented investigation which follows three paths. We perform numerical studies of HVCs with different masses passing through hot circumgalactic gas with different relative velocities and found that very high, but realistic speed leads to a sufficient compression of the clouds' centers so that Jeans mass can be exceeded. An important property is that HVCs are self-gravitating so that the overcome disruptive instabilities. Analogously, the same tendency is found in RPS models of dwarf galaxies. These results will be discussed with respect to external dynamical and energetic processes and the internal state of the gas. At third, we compare the models with observational properties of both, HVCs and RPS clouds of Virgo cluster galaxies with different conditions.

KEYWORDS high-velocity clouds, ram-pressure stripping, intergalactic clouds, star formation

IAUS 373

#1566

The SUNBIRD Survey: insights into small-scale star formation mechanisms through the NIR study of young massive clusters in a sample of starburst and luminous infrared galaxies

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Initially thought to only emerge in the extreme environments of strongly star-forming galaxies such as interacting luminous infrared galaxies (LIRGs), young massive star clusters (YMCs) have also been seen in more quiescent environments, such as in gas-poor normal spirals and in nearby dwarf galaxies. With their masses spanning between 104- 108 $M_{\odot}$, these peculiar objects represent the most massive and extreme form of star formation (SF) in nearby galaxies and they form whenever there is intense SF activity. Such factors make them a good tracer of small-scale SF mechanisms which are not yet fully understood and hence deserve a more comprehensive investigation.

This talk presents the star cluster luminosity functions (CLFs, dN/dL ~ L-α) of 34 nearby starburst galaxies and LIRGs from the SUNBIRD survey with the aim to determine the impact of the host galaxy environment on the cluster formation processes. Near-IR adaptive optics imaging of the targets (with distances 25 < DL < 135 Mpc) were taken using VLT/NACO and Gemini/NIRI instruments with a PSF resolution of 0.1". Such observations allow the detection of YMCs still embedded in the dusty nuclear regions and the study of potential cluster-righ galaxies lying at larger distances. Single power-law fits of the derived CLFs result in a slope α ranging between 1.53 and 2.41, with a median of 1.87 ± 0.23. We found that possible biases such as blending effects and the choice of binning should only flatten the slope by no more than ~0.15, especially for cases where the luminosity distance of the host galaxy is below 100 Mpc.

Our analyses suggest that galaxies with extreme SF activity such as interacting LIRGs are associated with shallower power-law slopes (α ~ 1.9) compared to those of low star formation rate (SFR) galaxies. We also find that (composite) CLFs on sub-galactic scales associated with the nuclear regions of cluster-rich targets (N ~ 300) have typically shallower slopes than the ones of the outer field by ~0.5. Finally, there is a (mild) correlation between α and both the host galaxy's (SFR) and SFR density, i.e. the CLF flattens with an increasing SFR and Sigma_SFR. The extreme environments of strongly star-forming galaxies are likely to influence the cluster formation mechanisms and ultimately drive the ongoing SF mechanism.

KEYWORDS galaxies: interactions, galaxies: star clusters, galaxies: star formation

IAUS 373
#660

Star forming clumps, rates and histories: the spatially resolved view in dense galaxy environments

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Integral field spectroscopic studies of galaxies in dense environments, such as clusters and groups of galaxies, have provided new insights for understanding how star formation proceeds, and quenches. I will present the spatially resolved view of the star formation activity and its link with the multiphase gas based on MUSE and multi-wavelength data of the GASP survey, discussing the link among the different scales (eg the link between the spatially resolved and the global star formation rate-stellar mass relation). I will present the spatially resolved signatures of different quenching physical mechanisms, and the detailed quenching histories of jellyfish (progenitors) and post-starburst (descendants) galaxies in clusters at z~0 and at z~0.4. I will show the combined HST, MUSE and ALMA view of star-forming clumps in disks but also those forming in situ in the tails of gas stripped by ram pressure stripping, presenting their sizes, stellar ages, masses, scaling relations at different wavelengths. Finally, I will show evidence for internally driven quenching due to AGN activity, and how the latter can be connected with external processes such as ram pressure.

KEYWORDS galaxy clusters, star formation, starforming clumps

IAUS 373
#324

How Feedback Affects Stellar and Galactic Evolution: Perspectives in the Era of High-resolution Simulations

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The community of numerical astrophysicists has benefited greatly from the ever-improving computing technology over the past decades. I will discuss the new possibilities in the upcoming era of high-resolution numerical studies to form stars and galaxies simultaneously, and highlight two early examples. In one example, using a high-resolution cosmological simulation of a quasar-host galaxy, I will describe how a previously never discussed stellar feedback channel may hold an important clue for the growth of supermassive black holes. In another example, I will discuss how stellar feedback resolved with sufficient resolution turns out to be a key to test the formation scenario of so-called dark matter-deficient galaxies.

KEYWORDS dark matter-deficient galaxy, supermassive black hole, high-resolution, simulation, galaxy merger

IAUS 373
#2785

Relative importance of different stellar feedback processes in dispersal of giant molecular clouds

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Giant molecular clouds (GMCs) are the primary sites of star formation in the universe. Feedback from young massive stars, namely stellar winds, radiation, and supernovae, profoundly influences the evolution of natal clouds and the surrounding interstellar medium, but quantitative study of GMC dispersal with self-consistent star formation and multiple feedback mechanisms has been lacking. We perform a suite of radiation magnetohydrodynamic simulations of star-forming GMCs accounting for all major forms of massive star feedback. For a range of initial cloud mass and surface density, we systematically explore the relative importance of feedback mechanisms by turning on and off each feedback and comparing the lifetime star formation efficiency, injected momentum, and timescale for gas removal. We will discuss the implication of our results for GMC lifecycle in different environments.

KEYWORDS giant molecular clouds, star formation, stellar feedback

IAUS 373
#1378

The SAMI Galaxy Survey: Using concentrated star formation and stellar population ages to understand environmental quenching

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We present our study of environmental quenching in galaxies using the distribution of current star formation and stellar population ages from the full Sydney-AAO Multi-object IFS (SAMI) Galaxy Survey. The SAMI Galaxy Survey sample is selected from the GAMA survey and 8 cluster regions. Therefore, our study covers 4 halo mass intervals: ungrouped galaxies, low mass groups (<10^12.5 M*), high mass groups [10^(12.5-14) M*] and clusters (>10^14 M*).

By using a star formation concentration index [C-index, log(r_50,Ha/r_50,cont)], we analyse the distribution of current star formation in each galaxy. We find that as halo mass increases, there is an increasing fraction of galaxies with a centrally concentrated star formation region (SF-concentrated). This provides evidence of outside-in quenching in groups, as well as in clusters. To understand quenching time-scales, we calculate Dn4000, Hdelta_A, light-weighted age (Age_L) and mass-weighted age with stellar population spectral fits. Then we compare the stellar population radial profiles in different environments. Compared to ungrouped regular galaxies, the age difference in the outer parts in high mass groups (1.53±0.42 Gyr for Age_L) suggests that there is a significant delay between the quenching of the outer disk and the total quenching of a galaxy. The age difference in high mass groups is larger than in clusters (0.23±0.33 Gyr for Age_L), which is consistent with cluster SF quenching being more rapid than in high mass groups.

KEYWORDS galaxies: evolution, galaxies:group, galaxies: star formation, galaxies: clusters: general

Quenching, bursting and galaxy shapes: colour transformation as a function of morphology

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The relative impact of different quenching mechanisms in galaxies at different cosmic epochs is still unknown. In particular, the relation between these processes and morphological transformation remains with understanding gaps. In this work, we measure the effectiveness of changes in star formation rates as a function of galaxy morphology by analyzing a new parameter, the Star Formation Acceleration (SFA). This methodology is capable of identifying both bursting and quenching episodes that occurred in the preceding 300 Myrs. We use morphological classification catalogs based on Deep learning techniques and our final sample has ~14,200 spirals and ~2,500 ellipticals. Between our findings, we have that elliptical galaxies in the transition region have median shorter quenching timescales (tau ~ 1 Gyr) than spirals (tau > 1 Gyr). This result conforms to the scenario in which major mergers and other violent processes play a fundamental role in galaxy evolution for most ellipticals. Such processes are responsible not only for quenching star formation more rapidly but also for playing a role in morphological transformation. We also find that two-thirds of galaxies bursting in the green valley in our sample are massive spirals with signs of disturbance. This follows the scenario where low-mass galaxies are losing their gas in an interaction with a massive galaxy: while the former is quenching, the last is being refueled and going through a burst, showing signs of a recent interaction. Lastly, we present a broader schematics scenario for galaxy evolution in the color-magnitude diagram following our recent findings.

KEYWORDS galaxies: evolution, galaxies: star formation, galaxies: spiral, galaxies: elliptical and lenticular, cD

IAUS 373
#983

Osaka feedback model II: Modeling supernovae based on high-resolution simulations

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Feedback from supernovae (SNe) is an essential mechanism that self-regulates the growth of galaxies, and a better model of SN feedback is still needed in galaxy formation simulations for the upcoming wide and deep galaxy survey programs. We build an SN feedback model based on high-resolution simulations of superbubble and SN-driven outflows for the physical understanding of the galaxy–CGM connection.

Using an Eulerian hydrodynamic code Athena++, we find universal scaling relations for the time evolution of momentum and radius for a superbubble, when the momentum and time are scaled by those at the shell-formation time. We then develop an SN feedback model based on the Athena++ simulation results utilizing Voronoi tessellation around each star particle, and implement it into the GADGET3-Osaka smoothed particle hydrodynamic code. Our feedback model is constructed to be isotropic and conservative in terms of energy and momentum.

We examined the mass/energy/metal loading factors, and found that our stochastic thermal feedback model produced galactic outflow that carries the metals high above the galactic plane but with weak suppression of star formation. Additional mechanical feedback further suppressed star formation and brought the simulation results in better agreement with the observations of the Kennicutt–Schmidt relation. Therefore, we argue that both thermal and mechanical feedback is necessary for the SN feedback model of galaxy evolution when an individual SN bubble is unresolved.

I will give an overview of the model, and present the results of isolated and cosmological zoom-in simulations using this model.

KEYWORDS galaxy formation, numerical simulation, stellar feedback, supernovae, galactic winds

Using Observables to Test Models

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There has been considerable progress in the field of galaxy evolution, on both the observational and theoretical sides. A particularly exciting phenomenon is the development of rich databases that can be used to constrain models. Indeed, most theories and models require data across the spectrum to be pulled together to place quantitative constraints. The rich phenomenology of galaxies and the large number of new facilities capable of delivering complex datasets, such as MUSE in the optical, JWST in the infrared, and ALMA at millimeter waves, is resulting in an abundance of data that need be systematically compared to predictions. In this talk I will discuss a few examples and I will highlight the importance of developing the tools and surveys needed to address the scientific issues at hand.

KEYWORDS galaxies, galaxy evolution, multi wavelength observations, model testing

IAUS 373
#2307

What drives galaxies from the main sequence to the green valley?

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Green valley galaxies (by selection) exhibit lower specific star formation rates and are thought to be in the transition from the active star-forming phase to the quiescent state. Physical mechanisms responsible for the depleted star formation in green valley galaxies, however, are still under debate. Using the ALMA-MaNGA Quenching and STar formation (ALMaQUEST) CO observations, we study the so-called 'resolved star formation scaling relations', which describe relationships among surface densities of star formation rate, stellar mass, and molecular gas mass. By comparing the kpc-scale scaling relations between the main sequence and green valley galaxies, we are able to quantify if the deficit of star formation in green valley galaxies is driven by depleted molecular gas or inefficient star formation. And finally, we will present our recent ALMA dense gas (HCN and HCO+) observations for a set of selected ALMaQUEST galaxies to discuss whether the green valley galaxies lack dense molecular gas or not.

KEYWORDS galaxies, star forming main sequence, green valley galaxies, molecular gas, spatially resolved observations

IAUS 373

#388

On the HI Content of MaNGA Major Merger Pairs

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The role of HI content in galaxy interactions is still under debate. To study the HI content of galaxy pairs at different merging stages, we compile a sample of 66 major-merger galaxy pairs and 433 control galaxies from the SDSS-IV MaNGA IFU survey. In this study, we adopt kinematic asymmetry as a new effective indicator to describe the merging stage of galaxy pairs. With archival data from the HI-MaNGA survey and new observations from the Five-hundred-meter Aperture Spherical Radio Telescope (FAST), we investigate the differences in HI gas fraction (fHI), star formation rate (SFR), and HI star formation efficiency (SFEHI) between the pair and control samples. Our results suggest that the HI gas fraction of major-merger pairs on average is marginally decreased by ~ 17% relative to isolated galaxies, implying mild HI depletion during galaxy interactions. Compared to isolated galaxies, pre-passage paired galaxies have similar fHI, SFR, and SFEHI, while pairs during pericentric passage have moderately decreased fHI (-0.18 ± 0.07 dex), significantly enhanced SFR (0.29 ± 0.11 dex) and SFEHI (0.44 ± 0.12 dex). When approaching the apocenter, paired galaxies show marginally decreased fHI (-0.07 ± 0.05 dex), comparable SFR (-0.02 ± 0.09 dex), and SFEHI (0.05 ± 0.08 dex). We propose the marginally detected HI depletion may originate from the gas consumption in fuelling the enhanced H2 reservoir of galaxy pairs. In addition, new FAST observations also reveal an HI absorber (NHI ~ 4.7 × 1021 cm-2), which may suggest gas infalling and the triggering of AGN activity.

KEYWORDS Galaxy interactions, Galaxy pairs, Galaxy mergers, Interstellar atomic gas, Star formation

IAUS 373
#1769

Evolution of Bulk Gas Flows from Starburst to Quiescent Galaxies

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Even though galactic winds are common in galaxies with starbursts or AGN, the role of such gas flows in galaxy evolution remains uncertain. Here we examine how winds vary along a likely evolutionary sequence connecting starburst to post-starburst to quiescent galaxies. To detect the interstellar medium and measure its bulk flows, we examine the residual NaD absorption line doublet after the stellar contribution has been removed from each galaxy's spectrum. We discover that outflows diminish along this sequence, i.e., as star formation ends. We then focus on the wind behavior within the post-starburst sample, for which we have measured the time elapsed since the starburst ended (post-burst age) via detailed modeling of their star formation histories (French et al. 2018). Even within our post-starburst sample, the fraction of galaxies with significant winds and the average wind velocities decrease with post-burst age after controlling for stellar mass.

KEYWORDS ISM: jets and outflows, ISM: kinematics and dynamics, galaxies: evolution, galaxies: ISM

WISDOM: Molecular cloud properties and star-formation quenching

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Using observations from the WISDOM survey that spatially resolve (1-30 pc) individual molecular clouds across the Hubble sequence, we reveal a clear dependence of the nature of the molecular interstellar medium of galaxies on Hubble type, and present a simple diagnostic of cloud formation. In particular, we highlight the shortcomings of the usual virial approach to clouds as self-gravitating objects, and stress the importance of the external galactic potential and in-plane shear to regulate the dynamical states of clouds. We also introduce a simple but powerful cloud-cloud collision formalism that accounts for the cloud properties in both nearby and high-redshift systems. Finally, we discuss the impact of these different mechanisms on the star formation efficiency of the clouds and thus the quenching of star formation, particularly in galaxy nuclei and spheroids (morphological quenching).

KEYWORDS Molecular clouds, Star formation, Galaxies

IAUS 373
#521

Investigating internal and external quenching mechanisms on various timescales

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The exact mechanisms behind how galaxies quench their star formation has been an ongoing problem in the field of galaxy evolution. With many confounding variables, determining which processes are dominant when a galaxy quenches is no simple task. Whether or not a galaxy quenches can depend on the individual properties of the galaxy, and/or the local environment of the galaxy. Thus, it is crucial to devise unique probes to uncover what factors bring galaxies to the end of their lives.

We have explored two approaches in this regard: quantifying the properties of recently-quenched galaxies in groups via central/satellite distinction, and using a measure of optical variability in galaxy lightcurves to identify trends between AGN activity and the evolutionary state of the galaxy. We have found strong links between recently-quenched galaxies and their environment, with low mass satellite galaxies being more susceptible to the gravitational effects of high halo mass groups. Subsequently, we found that galaxies classed as star-forming via emission-line ratios exhibit larger amounts of variability compared to galaxies classed as AGN, particularly at low stellar mass. Combining these results, we found that recently-quenched galaxies are more variable on average than AGN at the same stellar mass. These results add to the mounting evidence that optical variability can act as a viable tracer for low mass AGN and that AGN variability plays a significant role in the quenching and therefore evolution of the host galaxy.

KEYWORDS galaxies, evolution, star formation, AGN, quenching

IAUS 373

#479

Dissecting the star formation process at molecular cloud scale 8 billion years ago

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Clumpy HST rest-frame UV morphologies are ubiquitous among star-forming galaxies at z~1-3. Current observational findings favour that the observed UV-bright clumps with a median stellar mass of ~107 $M_\odot$ are star cluster complexes/associations formed in situ in high-redshift host galaxies rather than accreted satellites following a merger event. It has been proposed that they result from gas collapse due to gravitational instability in the galaxy disk, which at high redshift can fragment at larger scales than in local disks because of its gas-rich, turbulent nature. We bring new support to this clump formation mechanism by obtaining the first constraint on the stellar mass function of these UV-bright clumps at z~1-3, which we find follows a power law with a slope of -2. Such a power law is characteristic of local star clusters and HII regions, and is expected if turbulence-driven fragmentation is the mechanism responsible of their formation. The additional support to this clump formation mechanism comes from our detection of giant molecular clouds (GMCs) in two strongly lensed clumpy galaxies at z=1. The two galaxies were observed with HST and ALMA (in the CO(4-3) transition) at a similar angular resolution of 0.1” -0.15” , which with the help of strong gravitational lensing enables us to reach spatial resolutions reading down to 30 pc, i.e., comparable to what is achieved in local galaxies. The detected molecular clouds, although most appear as gravitationally bound structures, are different from the local GMCs: they are offset from the Larson scaling relations with more than 10 times higher molecular gas mass surface densities, almost 100 times stronger internal kinetic pressures, and 10 times enhanced internal supersonic turbulence. Only GMCs hosted in nearby starbursting/merger galaxies are comparable, supporting that GMCs form with physical properties that adjust to the ambient interstellar medium conditions prevalent in the host galaxy whatever its redshift. The detected GMCs are massive enough to be the parent gas clouds of the massive UV-bright stellar clumps observed in a comparable number in HST images and allow their in-situ formation. We estimate the efficiency of star formation per free-fall time to be higher than 10%.

KEYWORDS

IAUS 373

#2430

(Sub-)mm continuum surveys: mapping the dusty galaxy contribution to the star formation history

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We will review the efforts carried out in the last 10 years to map the contribution of dust-obscured star-forming galaxies to the overall history of star formation. While the contribution of bright submillimeter galaxies in the Ultra Luminous Infrared Galaxy regime (LIR> 1012Lsun) has been reasonably well characterized up to z~3, their contribution at larger redshifts is still a matter of debate. ALMA surveys have given us an initial view of the properties of dust obscuration in the Luminous Infrared Galaxy regime (LIR> 1011Lsun), while the statistical characterization of the rise and fall of obscured star formation at these luminosities still awaits larger and deeper surveys. We will introduce the open-access Legacy Surveys that the 50m Large Millimeter Telescope new imaging and polarimetry camera ToITEC will carry out, that will address these issues. We show the predictions derived from cosmologically motivated simulations.

KEYWORDS dusty galaxies, star formation, history, dust

IAUS 373
#1379

Spatially resolving the star formation activity of galaxies at 3 - 4 Gyrs of lookback time with MAGPI

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Given the complexity of the star formation histories of galaxies, it is not trivial to pinpoint the exact physical mechanisms responsible for the decline of the cosmic star formation activity from z ~ 2 to z ~ 0. By far, integral field spectroscopy (IFS) surveys such as MaNGA and SAMI have helped shed light on the physical processes at play by studying the spatially resolved star formation activity of galaxies at z ~ 0. These studies suggest that galaxies typically quench "inside-out", while those residing in dense environments tend to quench "outside-in". This motivates a further investigation into the evolution of star formation activity at higher redshifts, with the Middle Ages Galaxy Properties with Integral Field Spectroscopy (MAGPI) survey - a MUSE Large Program - extending the regime towards intermediate redshifts (z ~ 0.3). In this talk, I will be introducing the MAGPI survey and early results with the MAGPI data on the spatially resolved star formation activity of galaxies. In particular, I will present radial profiles of star formation rate (SFR) densities and metallicities of galaxies of different global star-forming states and compare them with those from z ~ 0 studies.

KEYWORDS galaxies, galaxy evolution, star formation

IAUS 373
#1061

Characterizing the Resolved Schmidt-Kennicutt Relation Using Different SFR Tracers at Cosmic Noon

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Understanding star formation across different environments and throughout cosmic time is key to understanding the numbers and characteristics of galaxies that we observe today. One of the critical assumptions and/or comparison points for simulations of galaxy evolution is the Schmidt-Kennicutt relationship—the correlation between galaxies' gas masses and their star formation rates (SFRs). At high redshifts, different tracers are often used to measure the SFR for

different galaxy populations, which make apples-to-apples comparisons difficult. These tracers are particularly sensitive to assumptions about dust extinction. In order to address this challenge, we have made spatially resolved (~1"=2kpc in the source plane) observations of three different SFR tracers of the strongly lensed z=2.26 "Main Sequence" disk galaxy SDSS J0901+1814: Hα from the VLT to capture less obscured star formation, IR continuum from ALMA to trace the obscured star formation, and 3GHz continuum as a putative extinction-free SFR tracer. We will compare these different tracers (and their combinations via resolved spectral energy distribution mapping) to molecular gas maps and show how they affect measurements of the Schmidt-Kennicutt relation. These results will critically inform surveys of resolved star formation at Cosmic Noon that use single-band SFR tracers, as well as comparisons between galaxy populations characterized at different wavelengths.

KEYWORDS galaxies, star formation, Schmidt-Kennicutt Relation, high-redshift, observational tracers

Resolving Star-forming Gas at the Peak Epoch of Star Formation

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Most of the stars in today's Universe formed around z~2 (the peak epoch of star formation), yet we know little about where and under which conditions they formed. Observations of local galaxies reveal that star formation typically proceeds in spiral arms/bars and that the star-forming (i.e. molecular) gas is distributed in a thin disk. But what about at z~2, a period during which galaxies had far higher gas fractions on average than today?

The answer requires resolved observations of molecular gas at z~2, but such observations are still rare and mostly biased to compact, dust-rich galaxies. In this talk I will present what we found by studying the highest-resolution observations of CO and FIR continuum emission in more typical star-forming galaxies at z~2. I will highlight what these observations imply for the sites of star formation at z~2 and will place these findings in context with recent simulation-based studies. I will also discuss the limitations of these "high-resolution" observations, providing a perspective for future work in this field.

KEYWORDS high-redshift galaxies, molecular gas, dust-continuum emission, ISM

IAUS 373

#650

Understanding quenching at high redshifts from local IFU surveys

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Post-starburst galaxies, quiescent galaxies whose recent star-formation rate dropped rapidly, are valuable proxies to understand the quenching process. However, getting spatially-resolved information of high-z post-starburst galaxies to investigate their physical origins is expensive or sometimes impossible.

For a more efficient alternative to study quenching at high-z, I present a sample of local (D<~100 Mpc) counterparts of high-z post-starburst galaxies. These galaxies have strong Balmer absorption and weak nebular emission lines measured from the spectra integrated over the entire SDSS MaNGA IFU plates; They would be identified as post-starburst galaxies if placed at high-z and observed by typical spectrographs.

Post-starburst galaxies in the distant Universe often show (1) positive stellar age gradients and (2) central compact weak star-forming regions, measured from marginal resolved data. The local counterparts have qualitatively the same radial profiles of stellar ages and star-formation activities but measured from well-resolved data. Follow-up observations are also easier and more efficient. I will show a summary of their star-formation profiles, AGN activities, and kinematics of gas and stars from the MaNGA IFU spectra, which inform us of the physical processes that drive quenching.

In summary, identifying and following up more local counterparts of distant post-starburst galaxies is a promising alternative to understanding quenching in the high-z Universe, where several kinds of observations will remain difficult or impossible even with coming observing facilities.

KEYWORDS quenching, poststarburst galaxies, galaxy stellar content

IAUS 373
#1357

The supply of gas through cosmic time: insights on the galaxy assembly at early epochs

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Remarkable progress has been made in the last few years in understanding the global properties of galaxies and how they evolve through cosmic time. Major focus has been given to studies of how the availability of molecular gas regulates the star-forming activity and galaxy growth, the eventual quenching of star formation, and how these mechanisms evolve through cosmic time. Most of these advances have been made thanks to ALMA and the upgraded capabilities of NOEMA. In this presentation, I briefly review the latest constraints on the molecular gas content based on different tracers of the interstellar medium (ISM; dust continuum and CO, [CI] and [CII] line emission), including recent determinations of the molecular gas fraction, gas depletion timescales, and molecular gas cosmic density provided by the recent ALMA programs out to z~7. Finally, I will concentrate on recent and on-going studies aiming to spatially and kinematically resolve the cold ISM and star formation activity down to kpc scales in galaxies out to z≤6-7, which represent an unprecedented view of the galaxy assembly and feedback processes in the early universe.

KEYWORDS galaxy:formation, galaxy: evolution, interstellar medium

IAUS 373
#385

The Chemical Evolution of Spiral Galaxies from Start of Cosmic Dawn to Today

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The spatial distribution of oxygen in the interstellar medium of galaxies is key to understanding how efficiently metals that are created in the hearts of massive stars are mixed and redistributed across the galaxy. I present a study of 6 nearby spiral galaxies using the 3D optical data obtained in the TYPHOON Program. We use HIIPhot to identify the HII regions within the galaxy based on the surface brightness of the H-alpha luminosity and measure the radial variations of the HII region oxygen abundance. We recover a flattening to the negative radial gradient in several of the galaxies at large galactocentric radius, suggesting that we have sufficient resolution and sensitivity to detect the metallicity floor, which may be set by direct accretion of gas from the cosmic web. The measured metallicity floor informs on the chemical enrichment of the galaxy and the outflow of metals to the outer regions of the disk from the enriched inner region of the galaxy disk through radial flows. I will present comparisons with hydrodynamical simulations to shed light on the dynamical local enrichment of the oxygen enrichment in these galaxies and the implications for galaxy evolution studies with the next generation of observatories including the upcoming James Webb Space Telescope.

KEYWORDS galaxies

IAUS 373
#1889

Resolving the ISM structure and kinematics in two star forming galaxies at z ~ 6

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Galaxies mergers are a dominant mechanism in the mass build-up of galaxies, as it triggers the consumption of cold molecular gas into stars. Recent studies focusing on the first billion years of the universe show evidence of significant merging activity in the early Universe ($z > 5$). It is supported by the findings of complex clumpy structures with often a mismatch between the stellar and cold gaseous component, which also indicates a high disturbance of the gas structure. High-resolution observations are mandatory to fully characterize the kpc-scales of mergers and investigate how these interactions can pollute the circumgalactic medium and how it can affect the star formation. We report high-resolution measurements of the [CII] emission line with ALMA for the two typical star-forming galaxies HZ3 and CLM1, respectively, at $z = 5.5$ and $z = 6.1$. HZ3 shows clear signs of a merger scenario, with a more extended [CII] emission than the UV counterpart. On the other hand, the compactness and stellar mass of CLM1 points to a compact merger scenario. The resolution (~0.3") of our observation allows us to study the spatial and kinematics properties at kpc-scales of the galaxies in order to characterize the interacting stages and properties of the individual clumps. We are able to understand what are the different mechanisms that lead to the (lack of) gas stripping and circumgalactic mixing of these first galaxies. This study will open interesting windows to the study of interacting systems in the ALMA high-resolution ongoing CRISTAL program for galaxies at $z > 5$.

KEYWORDS high-redshift, ISM, star-formation, structure, kinematics, mergers

IAUS 373
#1202

The evolution of quiescent galaxies from z = 0.6 to z = 1.3

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We present a study exploring the most massive high-redshift galaxies by considering the evolution of quiescent galaxy physical properties between redshifts z = 0.7 and z = 1.1. We use a combination of HST imaging with ultra-deep rest-frame UV-optical spectroscopy provided by the VANDELS and LEGA-C surveys, to constrain the relationships between galaxy stellar mass, age and physical size. The unprecedented size and quality of these novel high redshift spectroscopic datasets allow us to demonstrate for the first time that this downsizing trend (older galaxies at higher masses) is clearly evident at both redshifts. Robust measurements of the galaxy mass-size relation for both passive galaxy samples demonstrate that the median galaxy size increases by a factor of 1.9±0.1 over our redshift range, and also suggest that the slope of the mass-size relation becomes shallower over cosmic time. We finally demonstrate that, at fixed stellar masses, smaller galaxies have on average higher Dn4000 values than their larger counterparts, potentially indicative of a relationship between age and size, allowing us to constrain the level of progenitor bias and the role of minor mergers within this population.

KEYWORDS galaxies, high-redshift, star formation, evolution

IAUS 373
#308

How dusty quasars shape the inner regions of galaxies at cosmic noon

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The canonical picture of galaxy evolution invokes strong feedback from active galactic nuclei (AGN) to reduce the star formation efficiency of massive galaxies. This process can explain their observed scaling relations, which were already established by cosmic noon (z=2-3). However, the physical channels that allow energy and momentum released on sub-pc scales to affect gas on galactic scales are largely unconstrained. In this presentation, I show a direct link between dust-reddening and molecular outflows from quasars at z~2.5. By examining the dynamics of warm molecular gas in the inner regions of galaxies, we detect outflows from within the galactic bulges (~100 pc) with short timescales of 0.05 Myr that are due to ongoing energy output from the AGN. We observe outflows only in systems where quasar radiation pressure on dust is sufficiently large to expel their obscuring column densities. This agrees with theoretical models that predict radiation pressure on dust in the vicinity of the black hole is the major driving mechanism of galactic-scale outflows of cold gas. Our findings show that quasar radiation ejects star-forming gas from nascent stellar bulges at velocities comparable to those seen on larger scales in the ionised phase, and that molecules survive in outflows even from the most luminous quasars. We will detail how our results can inform observational tests of multi-phase AGN feedback and implementations of AGN feedback in next-generation cosmological simulations.

KEYWORDS AGN, galaxies, ISM, quasars, feedback

IAUS 373

#1747

The role of AGN outflows and jets in regulating star formation

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Theoretical arguments suggest that the energy released by the black hole at the center of most galaxies may play an important role in shaping the properties of the interstellar medium (ISM) and consequently regulating the accretion onto the central SMBH itself and the evolution of its host galaxy. In particular, AGN-driven, galaxy wide massive outflows as well as AGN-driven jets may be fundamental processes affecting the bulk of the baryons in the universe.

I will report on two large observational campaigns both at low-z and at cosmic noon, which combining ground based IFU observations to trace the ionized gas and ALMA observations to trace the moleucular gas try to:

a) derive the demography of AGN driven outflows and the incidence of small scale jets; b)trace the kinematics of the ionized gas phases in galaxies from sub-pc to hundreds of kpc; c) understand how the energy released by the AGN couple with the ISM and which impact this may have on the host galaxy's evolution.

Finally I would discuss some exciting perspective for this field of research with the first JWST observations.

KEYWORDS Galaxies, AGN, ISM

IAUS 373

#1481

Feedback models in galaxy simulations and probing their impact using cosmological hydrodynamic simulations

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Cosmological hydrodynamic simulations have become an indispensable tool to study the formation of galaxies and supermassive black holes (SMBHs) in a cosmological context. On large scales, the Lambda cold dark matter (LCDM) model is very successful, providing the backbone of large-scale structure in the Universe. However, on small scales (<1Mpc), our understanding of galaxy formation still has many gaps. In particular, the feedback from supernovae (SNe) and SMBHs plays a critical role in self-regulating the growth of galaxies and SMBH themselves, but their exact mechanisms are still unclear.

Some of the recent high-resolution zoom-in cosmological hydro simulations have achieved resolutions better than a few tens of parsecs (especially at high redshift). However, it is still difficult to simulate a large number of galaxies down to redshift z=0 with such a high resolution, without which detailed comparisons with extensive galaxy surveys are not possible. Therefore, physically plausible subgrid models are still necessary for cosmological hydro simulations with box sizes greater than 10Mpc (comoving) to obtain a decent sample of simulated galaxies.

This presentation will review some of the recent efforts to develop these feedback models in cosmological and galactic contexts based on high-resolution simulations of superbubbles in the ISM. I will also discuss examples of comparisons between cosmological hydro simulations and observations of galaxies and IGM tomography, and evaluate the possibility of distinguishing these subgrid models via structure formation. Furthermore, I will touch on the cross-correlation studies between different types of galaxies and HI gas at intermediate redshifts. These studies show that, in general, there is more abundant HI gas closer to the galaxies from IGM/CGM region, with about 20-30% variations in the Ly-alpha flux decrement due to different SN feedback models.

KEYWORDS galaxy formation, star formation, supernova, feedback, intergalactic medium, circumgalactic medium

IAUS 373
#2700

The evolutionary path of quenching galaxies and comparisons between theoretical and observational samples

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I will highlight how careful comparisons between observed and theoretical datasets can provide novel insights into star formation and quenching in galaxies. Additionally, I will describe how the evolutionary path of the quenching galaxies can be strikingly different at various moments in cosmic time and between different galaxy formation models, and how we can use these differences to improve our understanding of galaxy quenching.

The star forming and quiescent galaxy populations, from simulations or observed data, can vary significantly depending on the tracers and definitions used. We perform apples-to-apples comparisons of these populations across cosmic time between multiple large theoretical and observational datasets, based on carefully build synthetic galaxy spectra for all (~3e5) simulated galaxies. Using this wealth of spectral data, we describe the galaxy star forming sequence and the populations of star-forming, quiescent, and in-between galaxies in theoretical predictions, mock observations, and observational data, and compare these.

Moreover, we infer the required dust attenuation to match observed datasets and make predictions based on these, highlighting how different approaches to modeling the effects of dust leads to a diversity in predictions for galaxy star formation rates.

Finally, we follow the evolutionary path of the quiescent galaxy population at varying times in the history of the universe, and show how the past and future evolution of this population can widely differ across cosmic time and between different simulations with different galaxy formation models. We illustrate how this variation in evolutionary pathways needs to be taken into account when comparing quiescent galaxies across cosmic time, and how these may be used to provide insights into the physical processes governing galaxy quenching.

KEYWORDS galaxy formation and evolution, galaxy star-forming sequence, quiescent galaxies, galaxy quenching, comparisons between theory and observations, statistical samples, large cosmological simulations

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IAUS 373

#1996

Direct glimpse at accretion-driven galaxy evolution in the protocluster-era

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RO-1001, a galaxy group at z=2.91, has proved to be a treasure trove for studying galaxy-evolution within dense environments in the 'protocluster-era'. Deep KCWI observations (Daddi+2021) revealed a Ly-alpha halo tracing infalling streams of gas into the center of the group potential well, that is expected to be fueling prodigious levels of star-formation (a total of ~1250 $M_{\odot}$/yr) distributed over three sub-millimeter bright massive (>1011 $M_{\odot}$) galaxies. RO-1001 hence provides an ideal case study for the effects and limits of cold-gas accretion on galaxies. We use deep near-IR (HST/WFC3) and sub-mm (ALMA) imaging to map both stellar emission and star-formation of the star-forming member galaxies, resolved down to sub-kpc scales, and reveal extended quiescent lopsided disks that contain within them highly dust obscured star-bursting cores (Kalita+submitted). After obtaining supporting evidence from Keck MOSFIRE spectroscopic observations, comparisons to theory and simulations suggest the observed properties to be the first direct evidence of accretion-driven galaxy evolution through the use of morphological analyses. Moreover, we also observe an ancient (>1Gyr) quiescent galaxy within the same structure, illustrating accretion to not be a necessary mechanism to cause and maintain quiescence in massive galaxies (Kalita+21). This paves the way for follow-up studies on similar structures in the upcoming JWST era and initiates the discussion regarding the link between global evolution of cold-gas accretion streams and star formation in massive galaxies in our Universe on a case-by-case basis.

KEYWORDS Galaxy evolution, High redshift, Dense Environment, Quiescent galaxies, Star formation, Gas-accretion, Galaxy Groups

IAUS 373
#679

Rapidly growing supermassive black holes in extremely radio-loud galaxies

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We present the optical and infrared properties of 39 extremely radio-loud galaxies discovered by cross-matching the Subaru/Hyper Suprime-Cam (HSC) deep optical imaging survey and VLA/FIRST 1.4 GHz radio survey. The recent Subaru/HSC strategic survey revealed optically faint radio galaxies (RG) down to g_AB ~ 26, opening a new parameter space of extremely radio-loud galaxies (ERGs) with the radio-loudness parameter of log R_rest = log(f_{1.4GHz,rest}/f_{g,rest}) > 4 . Because of their optical faintness and small number density of ~1 deg^-2, such ERGs were difficult to find in the previous wide but shallow or deep but small area optical surveys. ERGs show intriguing properties that are different from the conventional RGs: (1) most ERGs reside above or on the star-forming main-sequence and some of them might be low-mass galaxies with log(Mstar/Msun) < 10. (2) ERGs exhibit a high specific black hole accretion rate, reaching the order of the Eddington limit. The intrinsic radio loudness (R_int), defined by the ratio of jet power over bolometric radiation luminosity, is one order of magnitude higher than that of radio quasars. This suggests that ERGs harbor a unique type of active galactic nuclei (AGN) that show both powerful radiations and jets. Therefore, ERGs are prominent candidates of very rapidly growing black holes reaching Eddington-limited accretion just before the onset of intensive AGN feedback.

KEYWORDS jet, AGN, radio galaxy, AGN feedback

IAUS 373
#856

Analysis of giant molecular cloud properties on FIRE-2 Mergers

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[4]*Physics and Astronomy, Pomona College, Canada*

FIRE-2 is a state-of-art simulation with a realistic feedback model that enables us to explore interstellar medium (ISM) properties at different phases. In this talk, I will present new results using FIRE-2 simulations to study giant molecular cloud (GMC) properties in galaxy mergers. Due to the rarity of mergers in the local universe, we do not have large samples of mergers that are close enough to study individual GMC properties. The FIRE-2 merger simulations provide us with a new window to study how GMCs evolve during a merging event. In this study, we conduct a pixel-by-pixel analysis on the molecular gas properties in both undisturbed control galaxies and mergers in the simulation. In the velocity dispersion versus gas surface density diagram, the data points from FIRE-2 galaxies follow a similar trend as that seen in observations of PHANGS normal spiral galaxies. However, the gas surface density of FIRE-2 galaxies sits at the lower surface density/velocity dispersion end compared to PHANGS galaxies, with a maximum surface density barely reaching 100 Msol/pc^2. Instead, the data points from the simulated galaxies lie closer to dwarf or green-valley galaxies, such as M31. We suspect the low gas surface densities might be caused by the low gas mass fraction due to the choice of simulation initial conditions. For the simulated mergers, we find the gas surface density is still low compared to several observed mergers. On the other hand, the gas in simulated mergers has high velocity dispersion that is comparable to the observed mergers. We calculate the virial parameters of GMCs in the simulated mergers and the virial parameters are much higher than that of normal spiral galaxies both in observations and simulations. This is consistent with our expectation that feedback from starburst activities will disperse the surrounding GMCs and make clouds less bound.

KEYWORDS galaxy mergers, giant molecular clouds, starburst

IAUS 373
#1034

Feedback and the Emergence of Star Formation Scaling Relations

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On both scales of individual GMCs, and scales of the global ISM, the primary source of energy is from massive, luminous stars. UV radiation, winds, and supernovae (directly and indirectly via cosmic ray acceleration) are responsible for both heating gas and for applying the forces that drive kinetic and magnetic turbulence. Since cooling times and turbulent dissipation times are generally quite short compared to evolutionary timescales, the observed state of ISM gas could not be achieved without these energy inputs. Correspondingly, maintaining balance in the energy and momentum equations has implications for the required energy input rates, and therefore for star formation rates and efficiencies. In this presentation, I will explain how observed star formation scaling relations, for both the global ISM and individual star-forming clouds, emerge from considerations of ISM quasi-steady equilibrium and energy inputs from stellar populations. The focus will be on theory and numerical radiation magnetohydrodynamic simulations, with comparisons to observations also included.

KEYWORDS ISM, Star Formation

IAUS 373

#2707

Modeling star formation across a vast range of spatial scales

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Star formation in galaxies may be regulated by processes occuring from the sub-pc scales of individual stars and supernovae, to 1-10 pc scales of molecular clouds, to kpc scales of spiral structure, to the Mpc scales of the cosmic web that funnels gas into halos. I will review the state of the art in simulations of star formation and stellar feedback within galaxy scale and cosmological simulations. In particular, I will describe a new multiscale approach for incorporating insights from simulations with a "resolved" treatment of the multiphase ISM and stellar feedback into large scale cosmological simulations. I will discuss the implications of these models for interpreting observations of gas, star formation, and galactic outflows.

KEYWORDS star formation, galaxy formation

IAUS 373
#932

Linking the rise and fall of star formation with the large-scale angular-momentum environment through circumgalactic medium

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The connection between halo gas acquisition through the circumgalactic medium (CGM) and galaxy star formation has long been studied. In this series of two papers, we put this interplay within the context of the galaxy environment on large scales (several hundreds of kpc), which, to a certain degree, maps out various paths for galaxy interactions. We use the IllustrisTNG-100 simulation to demonstrate that the large-scale environment modulates the circumgalactic gas angular momentum, resulting in either enhanced or suppressed star formation inside a galaxy.

In the former case, we show that the large-scale environment around a star-forming galaxy is often responsible for triggering new episodes of star formation. Such an episodic star formation pattern is well synced with a pulsating motion of the circumgalactic gas, which, on the one hand receives angular momentum modulations from the large-scale environment, yielding in-spiralling gas to fuel the star-forming reservoir, while, on the other hand, is affected by the feedback activities from the galaxy centre. As a result, a present-day star-forming galaxy may have gone through several cycles of star-forming and quiescent phases during its evolutionary history, with the circumgalactic gas carrying out a synchronized cadence of "breathing in and out" motions out to ~100 kpc.

In the latter case, we find that for present-day quenched galaxies, both the large-scale environments and the ambient CGM have always had higher angular momenta throughout their evolutionary history since at least z=2, in comparison to those around present-day star-forming disk galaxies. This angular momentum modulation results in less efficient gas inflow into the central star-forming gas reservoirs. A sufficiently high CGM angular momentum, as inherited from the larger-scale environment, is thus an important factor in keeping a galaxy quenched, once it is quenched. The process above naturally renders two key observational signatures: (1) a coherent rotation pattern existing across multiple distances from the large-scale galaxy environment, to the circumgalactic gas, to the central stellar disk; and (2) a possible anti-correlation between galaxy star-formation rates and orbital angular momenta of interacting galaxy pairs or groups.

KEYWORDS angular momentum, circumgalactic medium, star formation, quenching, gas acquisition, large-scale environment, IllustrisTNG

IAUS 373
#2070

Environmental dependences of molecular cloud lifecycle in 60 main sequence galaxies

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The processes of star formation and feedback take place on the scales of giant molecular clouds (GMCs; ~100 pc) within galaxies and play a major role in governing galaxy evolution. However, the detailed characteristics of these processes are unknown due to a lack of systematic observational constraints, and it is still a key open question which physical mechanisms regulate the evolutionary cycle between gas and stars in galaxies. By applying a robust statistical method to high-resolution multi-wavelength observations, we systematically measure the evolutionary timeline from molecular clouds to exposed young stellar regions, across an unprecedented sample of 60 star-forming main-sequence galaxies of the PHANGS survey. We find that clouds live for about 1-3 GMC crossing times (5-30Myr). CO and Halpha emission are found coincident for 1-5Myr, during which time stellar feedback efficiently disperses the surrounding molecular gas. These timescales show galaxy-to-galaxy variations, correlating with the galactic-scale environmental properties (e.g. molecular gas surface density, stellar mass). These correlations can be physically understood, revealing the role of galactic-scale dynamical processes on the small-scale evolutionary cycle of molecular clouds, star-formation, and feedback. Furthermore, in the 6 nearest galaxies of our sample, we have established that young stellar regions remain heavily obscured for 1-4Myr after the onset of massive star formation (10-25% of the cloud lifetime) and bright in 24um emission, before becoming also visible in Halpha. These results represent a major first step toward a comprehensive picture of cloud assembly and feedback, which will be extended to 19 more galaxies with our accepted JWST Large Program, allowing direct constraints on the processes at play during the earliest phases of star formation, as a function of galactic environment.

KEYWORDS giant molecular cloud, star formation, galaxy evolution, massive star feedback

IAUS 373
#919

What drives disk instabilities and star-forming clumps in galaxies at Cosmic Noon?

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The evolution of galaxies is dictated by their global morphology and kinematics, which drive the gas consumption and star-formation rise and fall. At the peak of star formation (cosmic noon), galaxies have complex morphological and kinematic structures, including a high incidence of star-forming clumps. At this epoch, the stellar specific angular momentum (j*) is low whereas molecular gas fractions (fgas) are high when compared to how they are in the local Universe. In the frame of Toomre instabilities, both the low j* and high fgas drive the high instabilities that lead to fragmentation and the formation of those star-forming clumps within the disks. We present a resolved study of a representative sample of 40 star-forming galaxies (23 disks) at z~[1.5-2.5] that have IFS data at different spatial resolutions with OSIRIS/SINFONI/KMOS as well as Hubble Space Telescope (HST) photometry, and where 16 also have global fgas measurements from ALMA or the Plateau de Bure interferometers. In order to study the ionized gas kinematics (via the Hα emission in star-forming regions) of the sample, we developed a code that simultaneously models the adaptive optics (AO) assisted observations along with their natural seeing (NS) counterparts at spatial resolutions of [0.1– 0.4] arcsec and [0.6– 1.0] arcsec, respectively. Spatially resolving these galaxies with AO allows to shed light on the details of star formation, distinguish disks from mergers, resolve bulges and clumps as well as quantify j* with lower uncertainties, none of which is possible with the NS data alone due to the effects of beam smearing. By measuring individual clumps and bulge-to-total ratios of these systems we assess their systematic effects in j* and investigate the relation between angular momentum, morphology, gas, SFR, and clumpiness at cosmic noon. For the subset of galaxies that also have global fgas measurements, we use the Toomre stability criterium to test which mechanism (low j* or high fgas) is more responsible for driving the formation and eventual demise of clumps within the systems.

KEYWORDS Galaxy, Angular Momentum, Gas fractions, Instabilities, Clumps, Star formation

IAUS 373

#727

How are Galactic Star Formation Rates Regulated? Role of Supernovae, UV Radiation, and Magnetic fields

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Structure formation in the universe is not a one-way process solely driven by gravity. One profound piece of evidence is that, on galactic scales, star formation proceeds at a rate two orders of magnitude below the maximum set by pressureless collapse. The inefficiency of gas consumption has been attributed to the effects of energetic feedback from massive stars that maintain the pressure support. The total pressure support consists of thermal, turbulent, and magnetic components. Each pressure component arises from intricate coupling between feedback in different forms and the interstellar medium (ISM) physics. We conduct a suite of simulations controlling physics ingredients -- supernova (SN), UV radiation, and magnetic fields -- to quantify the role of each in modulating pressure support and star formation rates (SFRs). We use the TIGRESS numerical framework that solves radiation-magneto-hydrodynamics equations with gravity in a local shearing box representing a patch of galactic disks. We resolve the energy-conserving stage of most SNe and follow UV radiation transfer with adaptive ray-tracing. We couple the radiation fields with a photochemistry module for non-equilibrium hydrogen abundances and equilibrium carbon and oxygen abundances, setting the heating and cooling processes self-consistently. We show that SNe are a dominant turbulence driver, and UV radiation is a major heating source for modulating thermal pressure. The magnetic component is maintained by dynamo activity, which is suppressed if SNe, rotation, or shear is missing. In normal star-forming disk galaxies modeled in this work, each missing physical ingredient does not result in catastrophic failure but up to a factor of two higher SFRs. However, SN-regulated ISM is vastly different from UV-regulated ISM, implying the ISM is shaped by full physics in concert.

KEYWORDS Star Formation, Intersetllar Medium, Feedback, Supernova, UV radiation

e-Posters

IAUS 373

#3387

Physical properties of 850-um selected sources in North Ecliptic Pole SCUBA-2 survey

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We present recently obtained SCUBA-2 850-μm imaging observations over the 2 deg2 region around the North Ecliptic Pole (NEP), where we detect 549 sources at 4σ significance. Combined with the previous S2CLS source catalog, the total number of 850-um selected sources is 647, among which we identify 514 reliable multi-wavelength counterparts for 449 sources. Based on the optical to submillimeter photometric points, the photometric redshift, infrared luminosity, stellar mass, star formation rate (SFR), and the AGN contribution to the infrared luminosity of the identified counterparts (i.e., SMGs) are estimated through the spectral energy distribution fitting. 850-μm SMGs are infrared-luminous galaxies at <z>=2.5 with log10(LIR/Lsolar)=11.5-13.5, with a mean stellar mass of log10(Mstar/Msolar)=10.90 and SFR of log10(SFR/Msolar yr-1)=2.34. On average, the SMGs show twice as large SFR as galaxies on the star-forming main sequence, and about 40 per cent of the SMGs lie above the main sequence line with a large offset.

KEYWORDS galaxies: high-redshift, galaxies: starburst, galaxies: evolution, submillimeter: galaxies

IAUS 373
#3382

ALMA fragmented source identification in OMC-2 north

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The Orion Molecular Cloud 2 (OMC-2) region in the northern part of Orion A (d= 400 pc) is known as an embedded protocluster containing a large number of infrared sources (400 pc-2; Lada & Lada 2003). In the OMC-2 region, fifteen young sources are clustering within three-millimeter sources, FIR3, FIR4, and FIR5 (Chini et al. 1997, Farlan et al. 2016). Using the Atacama Large Millimeter/submillimeter Array (ALMA), we have performed mosaic observations toward FIR 3, FIR 4, and FIR 5, covering an area of 0.35 pc x 0.23 pc (~2′.9 × 1′.9), in the 1.3 mm continuum, CO (J = 2--1) line, and SiO (J = 5--4) line emissions. We have achieved 3σ dust mass sensitivity of ~3 × 10-5 Msun at T = 15 K. We have achieved approximately 10 times smaller beam surface area compared to the previous studies. Based on the 1.3 mm dust continuum image, we identified 51 dense dust sources with the dust mass range between 4 × 10-5 and 1 × 10-2 Msun. With the CO (J = 2— 1) emission, we have identified 12 outflows associated with some of the detected dust sources. We evaluated the gravitational stability of the identified dust sources. No tendency of outflow alignments was found within the observed region. In addition, we detected SiO(J = 5--4) emission within the embedded cluster. The SiO emission seems to be associated with outflow and non-outflow originated shocked regions. Our results also show direct evidences of interaction between an energetic outflow driven from the FIR3 and the FIR4. In this poster, we discuss physical properties of identified dust sources, how identified molecular outflows interact with other cluster members, and how the interactions might affect the consequencial star formation within the embedded cluster at their earliest evolutionary stage.

KEYWORDS our galaxy, star formation, protocluster, protostellar outflow, low-mass star, intermediate-mass star

IAUS 373
#3374

Re-analysis of the gas fraction within dark matter halos in a semi-analytic galaxy formation model

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Most baryons in dark matter halos exist as stars, interstellar gas, and hot halo gas. The fraction of those depends on physical processes such as star formation and supernova feedback and is often used to understand galaxy formation. Especially, the fraction of stars, or, stellar-to-halo mass relation, is widely used. Contrastingly, the halo gas fraction has not been analyzed so seriously, in spite of its importance as known as the missing baryon problem. We focus on these fractions in our semi-analytic model of galaxy formation, v2GC, and try to understand why some fraction of gas remains in the Milky Way-sized halos despite the cooling time must be significantly short compared to the dynamical time.

KEYWORDS galaxy formation, gas cooling, star formation, large-scale structure of the Universe

IAUS 373
#3257

Construction of GALEX UV Catalog of Low-redshift Galaxies

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Detection of transients such as supernovae (SNe) and kilonvae (KNe) in early phase has recently become important for understanding the progenitor properties and multi-messenger astronomy. Predicting which galaxy has the higher probability of hosting the transient events would help detect the early phase of the events and get information on their progenitors. The SN and KN rates are known to be the function of star formation rate (SFR) of the host galaxy. The SFR of the galaxy can be estimated from ultraviolet (UV) luminosity. However, the UV magnitudes have been derived for a limited number of nearby galaxies. In this work, we introduce GALEX galaxy catalog to offer all-sky UV brightness of low redshift galaxies. As a first step of this research, we select nearby galaxies from the GLADE catalog. We derive the UV photometry of the galaxies from the GALEX AIS images, supplemented by NGS and MIS data observed from GALEX. From the near-UV (NUV) and far-UV (FUV) magnitudes, we calculate the SFRs of the galaxies, which will further be useful for estimating the SN and KN rate. The results are compared with previous GALEX UV catalog of galaxies. There will be an updated catalog based on this catalog for calculating KN rate of the galaxies in the future work.

KEYWORDS GALEX, UV, transient, catalog, local universe, star formation rate, galaxy

IAUS 373
#3341

Impact of Radiation Feedback on the Formation of Globular Cluster Candidates during Cloud-Cloud collisions

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Giant molecular clouds (GMCs) are known to be birthplaces of present-day star clusters. Although the star clusters tend to be less massive and compact than globular clusters (GCs), previous studies based on observations and simulations suggest that cloud collisions likely trigger star formation. To understand the impact of radiation feedback during the formation of a GC, we simulate a head-on collision of two turbulent GMCs. The idealized radiation-hydrodynamic simulations include photo-ionization, direct radiation pressure, non-thermal pressure due to multiple scattering of infrared and Lyman alpha photons, and Type II supernovae explosions. We find that a gravitationally bound, compact star cluster of mass MGC ~ 10^5 $M_\odot$ forms within ~ 3 Myr when two GMCs with mass $M_{GMC} = 3.6\times10^5$ $M_\odot$ collide. The GC candidate does not form in a single collapsing event but emerges due to the mergers of local dense gas clumps and gas accretion. The momentum transfer due to the absorption of the ionizing photon is the dominant feedback process that suppresses the gas collapse and photoionization becomes efficient once a sufficient number of stars form. The cluster mass is larger by a factor of ~ 2 when the radiation feedback is neglected, and the difference is slightly more pronounced (16%) when extreme Lyα feedback is considered in the fiducial run. In the simulations with radiation feedback, supernovae explode after the star-forming clouds are dispersed, and their metal ejecta are not instantaneously recycled to form stars.

KEYWORDS Globular star clusters, Young massive clusters, High-redshift galaxies

Star-forming Dwarf Galaxies in Filamentary Structures around the Virgo Cluster: Probing Chemical Pre-processing in Filament Environments

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It has been proposed that the filament environment is closely connected to the pre-processing of galaxies, where their properties may have been changed by environmental effects in the filament before they fell into the galaxy cluster. We present the chemical properties of star-forming dwarf galaxies (SFDGs) in five filamentary structures (Virgo III, Leo Minor, Leo II A, Leo II B, and Canes Venatici) around the Virgo cluster using the Sloan Digital Sky Survey optical spectroscopic data and Galaxy Evolution Explorer ultraviolet photometric data. We investigate the relationship between stellar mass, gas-phase metallicity, and specific star formation rate (sSFR) of the SFDGs in the Virgo filaments in comparison to those in the Virgo cluster and field. We find that, at a given stellar mass, SFDGs in the Virgo filaments show lower metallicity and higher sSFR than those in the Virgo cluster on average.

We observe that SFDGs in the Virgo III filament show enhanced metallicities and suppressed star formation activities comparable to those in the Virgo cluster, whereas SFDGs in the other four filaments exhibit similar properties to the field counterparts. Moreover, about half of the galaxies in the Virgo III filament are found to be morphologically transitional dwarf galaxies that are supposed to be on the way to transforming into quiescent dwarf early-type galaxies. Based on the analysis of the galaxy perturbation parameter, we propose that the local environment represented by the galaxy interactions might be responsible for the contrasting features in chemical pre-processing found in the Virgo filaments.

KEYWORDS Dwarf Galaxies, Star Formation, Filamentary Structures, Pre-processing, Chemical Evolution

IAUS 373

#3300

Gas Infalling Motions in the Envelopes of Very Low Luminosity Objects

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We present the results of a single-dish survey toward 95 very low luminosity objects (VeLLOs) in optically thick (HCN 1−0) and thin (N2H+ 1−0) lines performed for the purpose of understanding the physical processes of inward motions in the envelopes of the VeLLOs and characterizing their true nature. The normalized velocity differences (dVHCN) between the peak velocities of the two lines were derived for 41 VeLLOs detected in both lines. The δV distribution of these VeLLOs is found to be significantly skewed to the blue, indicating the dominance of infalling motions in their envelopes. The infall speeds were derived for 15 infall candidates by using the HILL5 radiative transfer model. The speeds were in the range of 0.03−0.3 km s−1, with a median value of 0.16 km s−1, consistent with the gravitational freefall speeds from pressure-free envelopes. The mass infall rates calculated from the infall speeds are mostly of the order of 10−6 Msun yr−1, with a median value of (3.4 ± 1.5) × 10−6 Msun yr−1. These are found to be also consistent with the values predicted with the inside-out collapse model and show a fairly good correlation with the internal luminosities of the VeLLOs. This again indicates that the infall motions observed toward the VeLLOs are likely to be due to the gravitational infall motions in their envelopes. Our study suggests that most of the VeLLOs are potentially faint protostars, while two of the VeLLOs could possibly be proto−brown dwarf candidates.

KEYWORDS protostars, brown dwarfs, Collapsing clouds

#3270

Is star formation in bars suppressed?

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Because bar structure is a common feature of disk galaxies in the local universe, unveiling the properties of star formation (SF) in the bar is important for understanding the SF process in galaxies. Previous observational and theoretical studies have supported the idea that SF activity is suppressed in the bar (the region between the center and bar-end). On the other hand, recent statistical studies have reported that the SF efficiency (SFE) in the bars is not systematically lower than those in the arm (e.g. Muraoka+19, Diaz-Garcia+21, Querejeta+21). However, the definition of the bar regions in these statistical studies also includes center and bar-end. We, therefore, investigated the SFEs along the bars in nearby barred spiral galaxies by distinguishing three different bar structures: center, bar, and bar-end. The CO(1-0) and CO(2-1) datasets were obtained from previous CO surveys (e.g. PHANGS, COMING) and ALMA archival data. SFRs were derived from WISE 22 um and GALEX FUVs. To distinguish the three regions, we targeted 37 galaxies with bar structures larger than 5 times the angular resolution of the WISE 22 um (16.8 arcsec). The resulting SFE in the bars is 0.63 times lower than that in the disks, which suggests the SFE in the bars tends to be systematically suppressed. The reason for the different results from previous studies may be due to the strict distinction of the regions. Furthermore, we found a negative correlation between the degree of suppression and the velocity width of the CO emission lines. This result suggests that differences in shear strength or molecular cloud collision velocity control the SF.

KEYWORDS Star formation, CO, molecular gas, barred galaxy

IAUS 373
#3256

Blue-cored dwarf early-type galaxies in isolated environments: breathing dwarfs in sustaining star formation?

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Early-type dwarf galaxies (dEs), the most abundant low-luminosity systems in the nearby Universe, have been recently shown to exhibit an unexpected diversity in their properties, despite their rather unspectacular appearance. Particularly, the presence of blue-cored dEs with hints of recent or ongoing star formation at their centers, dubbed as dE(bc), in the cluster and group environments supports the scenario of late-type galaxy infall and subsequent transformation into red, quiescent dEs by environmental effects. Using SDSS DR12 optical and GALEX ultraviolet (UV) data, we discover 36 dE(bc)s exhibiting blue cores and positive color gradients in the field environment at $z < 0.01$. Based on the UV - r color-magnitude relation and star formation rate, we find that field dE(bc)s show different stellar population properties with more vigorous recent star formation in their central regions than counterparts in the Virgo cluster. While several transformation mechanisms for dE(bc)s in cluster environment have been proposed, all of these processes are not relevant to the field environment. We discuss a scenario of episodic star formation sustained by cosmic gas accretion in which star-bursting blue compact dwarf galaxy (BCD) - quiescent BCD cycle can be repeated during the Hubble time. In this cadence, we propose that field dE(bc)s might be quiescent BCDs at pre- or post-BCD stages but will eventually become passive dEs once they enter the cluster environment.

KEYWORDS early-type dwarf galaxy, blue compact dwarf galaxy, star formation, isolated environment

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#3194

The first detection of deuterated water toward extragalactic hot cores with ALMA

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We report the first detection of deuterated water (HDO) in extragalactic hot cores. The HDO 211-212 line has been detected with the Atacama Large Millimeter/submillimeter Array (ALMA) toward hot cores N105-2A and 2B in the N105 star-forming region in the low-metallicity environment of the Large Magellanic Cloud (LMC), the nearest star-forming galaxy. The metallicity of the LMC ($Z = 0.3\text{-}0.5\ Z_\odot$) is similar to galaxies at the peak of star formation in the Universe (redshift~1.5), making it an ideal template for understanding star formation processes at earlier cosmological epochs.

The N105 star-forming region lies at the western edge of the LMC bar and hosts H2O, OH, and CH3OH masers, ultracompact H II regions, and young stellar objects. We have compared the HDO line luminosity (LHDO) measured toward two hot cores in N105 to those observed toward a sample of 17 Galactic hot cores covering three orders of magnitude in LHDO, four orders of magnitude in bolometric luminosity (Lbol), and a wide range of Galactocentric distances (from ~0.1 to 19 kpc), and thus metallicities (from ~1.8 $Z_\odot$ toward the Galactic Center to ~0.25 $Z_\odot$ in the outer Galaxy). The observed values of LHDO for the LMC hot cores fit very well into the LHDO trends with Lbol and metallicity observed toward the Galactic hot cores. We have found that LHDO seems to be strongly dependent on the source luminosity, but metallicity also plays a role. We provide a rough estimate of the H2O column density and abundance ranges toward the LMC hot cores by assuming that the HDO/H2O ratio toward the LMC hot cores is the same as in the Galaxy; the obtained values are systematically lower than those measured in the Galactic hot cores. The spatial distribution and velocity structure of the HDO emission in N105-2A is consistent with HDO being the product of the low-temperature dust grain chemistry. Our results are in agreement with the astrochemical model predictions that HDO is abundant regardless of the extragalactic environment and should be detectable with ALMA in other external galaxies.

KEYWORDS Star formation, Astrochemistry, Magellanic Clouds, Chemical abundances, Protostars

IAUS 373
#3189

Anatomy of Diverse Galactic Star Formation History: Roles of Changing Mode of Gas Accretion, Different Feedbacks, and Gas Recycling

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Recent observations reveal a rich variety in galactic star formation history (SFH). Those diverse SFHs are likely to be linked to the morphological variation observed in the present-day galaxy populations (2020, MNRAS, 494, L37; 2022, MNRAS, 510, 1772; see also abstract No.3167). Based on the new results obtained by a simple evolution model, we argue that this diversity in SFH basically originates in the transition from the cold-mode to the hot-mode of halo gas accretion and is further modulated by feedbacks of different types and the interstellar gas recycling. The cold-mode accretion occurs in nearly free-fall for halo masses below the critical mass, Mcrit, and can potentially support active star formation (SF). SF slows down when the halo mass grows above Mcrit and the accretion timescale is switched to the radiative cooling time of the shock-heated gas (hot-mode). Mcrit is set by the shock stability for the halo gas and stays nearly constant at low redshift. At high redshift, the existence of cold gas filaments defines Mcrit, which increases with redshift. The decrement in star formation rate (SFR) caused by the accretion-mode transition in massive halos is more dramatic and occurs earlier than that in less massive halos due to this redshift-dependence of Mcrit, and this phenomenon partially explains the mass-dependent SFH revealed by the abundance matching analysis. Suppression of SF by the ejective feedback caused by supernovae that expels the interstellar medium (ISM) occurs through the whole life of low mass halos and after the intense SF around z=2 in high mass halos. The preventive feedback that prevents the gas from entering the halo and/or accreting onto the disk operates predominantly in low mass halos. These feedbacks reduce the stellar mass, M*, at the present epoch. The recycling (re-incorporation) of the ejected ISM acts to keep some of otherwise lost ISM for use in later SF and lifts up the present M* for the entire mass range. The two-phase gas accretion (cold and hot modes) aided by these ancillary processes successfully reproduces the stellar-to-halo mass ratio, the downsizing behavior in the stellar mass buildup, and the evolution of star-forming main sequence (SFR-M* relation) revealed by the observation.

KEYWORDS star formation history, gas accretion modes, feedbacks, ISM recycling, star-forming main sequence, downsizing, stellar-to-halo mass ratio

IAUS 373

#3167

Diverse Star Formation History in the Presence of Cold-Mode Gas Accretion: From Solar Neighborhood to Distant Galaxies

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Recent cosmological simulations reveal two kinds of gas accretion onto forming galaxies. The cold-mode gas accretion is rapid free-fall accretion of unheated halo gas and prevails below the critical halo mass, Mcrit, which is nearly constant in low redshift but increases with redshift in early times.

The hot-mode accretion is dominant in high mass halos at late times above Mcrit, and proceeds with the radiative cooling timescale of the halo gas.

My work addresses implications of this dichotomy for galaxy evolution using a simple toy model. For the solar neighborhood, this dichotomy causes a sudden change from fast star formation (SF) to slow SF with a hiatus of SF in between, as the growing halo transits from the cold mode to the hot mode.

This separation of SF into two regimes produces the bimodality in the stellar abundance pattern as observed in the solar neighborhood. Namely, the early fast SF produced metal-poor (low [Fe/H]) stars with enhanced α-elements (regarded as the thick disk stars), whereas the late slow SF produces a metal-rich low-[α/Fe] population (regarded as the thin disk stars) due to delayed iron enrichment by Type Ia supernovae (2018, Nature, 559, 585). Extending this model to a wide range of the halo mass, under the assumption that different accretion modes create different galactic components, leads to successful reproduction of the observed diversity in the present galactic structure (2020, MNRAS, 494, L37). Halos with small present masses evolve in the cold-mode regime most of time and are dominated by the thick disk. On the other hand, the extention of Mcrit into higher halo masses at high redshift (around z=2-3) leads to active SF in massive halos that is considered to produce bulges observed in today's massive galaxies. Thin disk components are formed by the hot-mode accretion. This result explains the observed trend that the mass fraction of the thick disk decreases while that of the bulge increases with the total stellar mass of the galaxy. This model also predicts that the mean stellar age of the bulge and the internal age spread within the bulge both increase with the galaxy total stellar mass, in agreement with the recent observation (2022, MNRAS, 510, 1772).

KEYWORDS cold-mode accretion, chemical bimodality, the Milky Way, galactic bulges, thick disks, thin disks, two-stage star formation

IAUS 373

#3152

The First Epoch of Cluster Assembly: the galaxy morphology- density and passive-density relations at z~2-3

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It is a well-known fact that most early-type (ETG) and passive galaxies inhabit dense environments at z<1.3. This is a key insight into the drivers of galaxy evolution, but the question remains how these well-known morphology-density and passive-density emerge from higher redshift. To address this question, we performed an in-depth study of galaxies in 16 spectroscopically confirmed clusters at 1.3<z<2.8 from the Clusters Around Radio-Loud (CARLA) AGN survey. CARLA is ideally suited for this study because it efficiently identifies clusters at z>1.3, and has a unique multi-wavelength coverage with HST, Spitzer and ground-based imaging and HST grism spectroscopy. We find that the morphology-density and passive-density relations are already in place at z~3 and 2, respectively. The cluster ETG and passive fractions depend on local environment and mildly on galaxy mass. Interestingly, we also find evidence of high merger fractions in our clusters with respect to the CANDELS fields, as invoked by previous studies to explain high quiescent fractions at z < 1.5. All the spectroscopically confirmed CARLA clusters have properties consistent with clusters and proto-clusters, confirming that RLAGN are lighthouses for dense environments.

KEYWORDS

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#3103

KMTNet Nearby Galaxy Survey. III. Deficient Hα Flux in the Extended Disks of Spiral Galaxies

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We perform a deep, wide-field imaging survey of nearby galaxies using Hα and broadband filters to investigate star formation characteristics in galaxies. Motivated by the finding that star formation rates (SFRs) derived from Hα fluxes in dwarf galaxies are systematically lower than those inferred from far-ultraviolet (FUV) fluxes, we attempt to determine whether the same issue occurs in the extended disks of two star-forming galaxies. We perform spatially resolved photometry using grid-shaped apertures to measure star-forming regions' FUV and Hα fluxes. To correct the fluxes for the internal properties of individual regions, such as attenuation and LyC escape, we also perform spectral energy distribution (SED) fittings using 11 photometric data points (FUV-to-MIR), including data from the literature. Comparing SFRFUV and SFRHα, converted from the corrected Hα and FUV fluxes, we find that SFRHα and SFRFUV appear to be inconsistent except for the central regions of galaxies, and SFRHα/SFRFUV tends to decrease as the SFR decreases. We evaluate possible causes of this discrepancy between the two SFRs by restricting parameters in the SED fitting and conclude that deficient Hα fluxes in the extended disks of galaxies are tightly correlated with recent starbursts. The intense and short starburst, rapidly suppressed over the last 10 Myr, seems to induce a significant discrepancy between the SFRHα and SFRFUV. In addition, the recent bursts in the extended disks of galaxies appear to have occurred azimuth-symmetrically, implying that these were likely triggered by gas accretion or internal processes rather than external perturbation.

KEYWORDS Galaxies, Galaxy Properties, Star formation, Photometry

IAUS 373

#3089

SWAG: The maps

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We present maps of the 'Survey of Water and Ammonia toward the Galactic center' (SWAG). SWAG was observed with the Australia Telescope Compact Array (ATCA) at about 26" or ~1pc resolution at the distance of the Galactic Center. The survey was observed over three years (~550h), and covers the entire Central Molecular Zone between 21.2-25.6GHz range, targeting tens of spectral lines and 4GHz of continuum. Here, we present some final maps of molecular transition. These include multiple NH3 lines, radio recombination lines, thermal C3H2, CCS, CH3OH, HC5N, HNCO, OCS, and SO2 lines, as well high resolution 22GHz water masers. The maps are the foundation for ongoing comprehensive temperature mapping of the Central Molecular Zone, including the identification of heating mechanisms, the characterization of water maser sources as young stellar objects or AGB stars, as well as chemistry, dynamics, and star formation studies of the ISM in this unique environment.

KEYWORDS molecular gas, galactic center, star formation

IAUS 373

#3086

The Anomalous Ammonia Spectrum of Arp220

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Ultra-luminous infrared galaxies are extreme in many ways. The major mergers trigger star formation at very high rates that cause the ISM to be dominated by IR photons. Their dusty and opaque interior is therefore constantly exciting gas to higher levels doe to colissions and FIR excitation. We show the ammonia spectra toward the two cores of Arp220, the nearest ultra-luminous infrared galaxy, in three Very Large Array bands (Ku, K, Ka). Typical decay times of the non-metastable transitions are of order 100s and are therefore usually difficult to observe, except for the lowest ones in some extreme Galactic and extragalactic star forming regions. The FIR excitation of Arp220, however, shows that non-metastable states are widely populated up to a limiting energy exceeding 1000K. We assume that this atypical ammonia spectrum is due to the strong FIR field that re-excites the ammonia molecule on timescales much shorter than the already short decay times. The resulting level population causes a break-down of the typical assumptions made for the use of ammonia as a molecular thermometer.

KEYWORDS molecular lines, arp 220, ultraluminous FIR galaxies

IAUS 373
#3069

The Environments of CO Cores and Star Formation in the Dwarf Irregular Galaxy WLM

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The low metallicities of dwarf irregular galaxies (dIrr) greatly influence the formation and structure of molecular clouds. These clouds, which consist primarily of H2, are typically traced by CO, but low-metallicity galaxies are found to have little CO despite ongoing star formation. In order to probe the conditions necessary for CO core formation in dwarf galaxies, we have used the catalog of Rubio et al. for CO cores in WLM, a Local Group dwarf with an oxygen abundance that is 13% of solar. Here we aim to characterize the galactic environments in which these 57 CO cores formed. We grouped the cores together based on proximity to each other and strong FUV emission, examining properties of the star-forming region enveloping the cores and the surrounding environment where the cores formed. We find that high H I surface density does not necessarily correspond to higher total CO mass, but regions with higher CO mass have higher H I surface densities. We also find the cores in star-forming regions spanning a wide range of ages show no correlation between age and CO core mass, suggesting that the small size of the cores is not due to fragmentation of the clouds with age. The presence of CO cores in a variety of different local environments, along with the similar properties between star-forming regions with and without CO cores, leads us to conclude that there are no obvious environmental characteristics that drive the formation of these CO cores. Funding for this work was provided by the National Science Foundation through grant AST-1907492.

KEYWORDS Local Group, Dwarf Irregular Galaxies, Star Formation

IAUS 373
#3067

The spatially resolved star formation histories of post-starburst galaxies in SDSS-IV MaNGA

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We present a detailed study of the spatially resolved star formation histories (SFHs) of 67 post-starburst (or "E+A") galaxies using integral field data from the Mapping Nearby Galaxies at Apache Point Observatory (MaNGA) in the fourth-generation Sloan Digital Sky Survey (SDSS-IV). These galaxies are identified as post-starburst based on their high fraction (> 12.5%) of spaxels with strong stellar Balmer absorption lines (indicating a recent starburst) and weak nebular emission lines (indicating no ongoing star formation). This new approach selects roughly eight times as many post-starburst galaxies when compared to traditional techniques that use the integrated spectrum, but is also tuned to recover the subset of traditionally-selected galaxies. The two-dimensional (2D) spatial distribution of post-starburst signatures varies widely among our galaxies, whereas traditional methods find mostly centrally concentrated post-starburst regions. We apply stellar population synthesis models to fit the SFHs over the 2D maps, finding that more than half of our galaxies exhibit statistically significant one-dimensional (1D) radial trends in inferred physical parameters such as the time elapsed since the beginning of the starburst (or "burst age") and the fraction of the stellar mass produced in the starburst (or "burst fraction"). For galaxies that exhibit significant radial trends, two-thirds have positive trends while one-third have negative trends. These variations among radial gradients suggest different evolutionary processes are responsible for the creation of post-starburst galaxies, i.e., both inside-out and outside-in star formation.

KEYWORDS galaxies: general, galaxies: starburst, galaxies: star formation

IAUS 373

#3039

High-resolution ALMA study of CO J=2-1 line and dust continuum emissions in cluster galaxies at z=1.46

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Galaxy clusters in the present universe have a higher fraction of elliptical galaxies compared to low-density environments. To understand the origin of this environmental effect, observing an active phase of star formation in high-redshift clusters is thought to be effective. We present new ALMA results obtained from spatially resolved CO J =2–1 line (0.4″ resolution) and 870μm continuum (0.2″ resolution) observations of cluster galaxies in XMMXCS J2215.9-1738 at z = 1.46. Our sample comprises 17 galaxies within ~0.5 Mpc (0.6R200) from the cluster center, all of which have been detected in CO J =2–1 line previously in a lower resolution. The effective radii of both CO J =2–1 line and 870μm dust continuum emissions are robustly measured for nine galaxies by modeling the visibilities. We find that the CO J =2–1 line emission in all of the nine galaxies is more extended than the dust continuum emission by a factor of 2.8 ± 1.4. We investigate the spatially resolved Kennicutt-Schmidt (KS) relation in two regions within the interstellar medium (ISM) of the galaxies. The relation for our sample reveals that the central region (0 < r < Re,870μm) of galaxies tends to have a shorter gas depletion timescale, i.e. a higher star formation efficiency (SFE), compared to the extended region (Re,870μm < r < Re,CO). Overall, our result suggests that star formation activities are concentrated inside the extended gas reservoir, possibly resulting in the formation of a bulge structure. We find consistency between the ALMA 870μm radii of star-forming members and the HST/1.6μm radii of passive members in a mass-size distribution, which suggest transition from star-forming to passive members within ~0.5 Gyr. In addition, no clear differences in the KS relation and in the sizes are found between galaxies with and without a close companion. The content of this research is accepted for the

KEYWORDS high-redshift cluster, ALMA, size, structure formation

IAUS 373

#1834

Parsec scale CO depletion in KAGONMA 71, or a star-forming filament in CMa OB1

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In observational studies of infrared dark clouds, the number of detections of CO freeze-out onto dust grains (CO depletion) at pc-scale is extremely limited, and the conditions for its occurrence are, therefore, still unknown. We report two new objects where pc-scale CO depletion is expected. As a part of Kagoshima Galactic Object survey with Nobeyama 45-m telescope by Mapping in Ammonia lines (KAGONMA), we have made mapping observations of the NH$_3$ inversion transition lines toward the star-forming filament associated with CMa OB1. By comparing spatial distributions of NH$_3$(1,1) and C^{18}O(J=1--0), an intensity anti-correlation was found in IRAS 07077-1026 and IRAS 07081-1028. Furthermore, we obtained a smaller abundance of C^{18}O in at least IRAS 07077-1026 than in the other parts of the filament. After examining the dissipation of the high-density gas, photodissociation, and depletion, we concluded that the intensity anti-correlation in IRAS 07077-1026 is due to CO depletion. On the other hand, in PGCC G224.28-0.82, the emission line intensities of both NH$_3$(1,1) and C^{18}O(J=1--0) were strongly detected, although the gas temperature and density were similar to IRAS 07077-1026. There are bright protostars (bolometric luminosity L_bol > 100 $L_\odot$) only near PGCC G224.28-0.82. This may suggest that the non-thermal desorption, such as photodesorption of molecules from dust grains, has an essential effect even on the pc-scale.

KEYWORDS ISM, star formation, CO depletion

IAUS 373

#3026

An unprecedented view of the CNM in molecular clouds revealed by ESPOIR

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The transition from HI to H2 is one of the major bottleneck processes toward star formation. Among two flavors of HI, the cold and warm neutral medium (CNM and WNM), the cold one likely plays a key role thanks to its higher density. Despite its expected importance for the HI-to-H2 transition and ensuing star formation, however, the CNM in and around molecular clouds remains largely unexplored. In this talk, we present ESPOIR (hope in French; Earliest stage of Star formation Probed by Observations of InterstellaR absorption), a ~100 hr VLA project to measure HI absorption toward ~70 continuum sources behind the Perseus molecular cloud. Leveraged by the high sensitivity of the VLA, this project almost triples the number of existing measurements with a factor of 20 higher source number density (~1 src/deg2). The observations were finished in October 2020, and preliminary results show that the CNM fraction increases, while the spin temperature decreases, from the outskirt to the main body of Perseus, implying a strong association between the CNM and the formation of molecular gas. With the unprecedentedly high source number density, ESPOIR will enable us to examine the properties of the CNM in and around Perseus in detail and evaluate the role of the CNM in the formation and evolution of molecular clouds for the first time.

KEYWORDS interstellar medium, molecular clouds

IAUS 373
#2842

Colour gradients of low-redshift galaxies in the DESI Legacy Imaging Survey

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Radial colour gradients within galaxies arise from stellar population gradients. Large samples of colour gradients from wide-area imaging surveys can complement much smaller samples from integral-field spectroscopy and provide statistical constraints on galaxy formation models. Here we measure colour gradients for low-redshift galaxies ($z < 0.1$) using photometry from the DESI Legacy Imaging Survey. Our sample comprises ~ 63, 000 galaxies with spectroscopic redshifts and ~ 480, 000 galaxies with photometric redshifts. We find the colour gradients of most galaxies in this sample are negative (redder at 0.5 R_{eff} than R_{eff}), consistent with the literature. We investigate the relationship between colour gradient, average $g - r$ and $r - z$ colour, Mr, $M_\star$, and sSFR. Trends of gradient strength with M_r ($M_\star$) show an inflection around Mr ~ –21 ($\log_{10} M_\star$/Msun~ 10.5). Colour gradients become steeper with increasing $M_\star$ below this mass, whereas colour gradients in more massive galaxies become shallower. We also compute colour gradients for Illustris-TNG galaxies using mock images. The trends with Mr and $M_\star$ in the simulation are consistent with our observational results but the trends with $g - r$ and sSFR are different. We attribute this to an excess of low-redshift star formation in massive TNG galaxies. Overall, our results support concordance ΛCDM galaxy formation theory, in which massive galaxies assemble inside-out through gradual dissipative collapse, giving rise to steeper gradients with increasing mass, until star formation is strongly suppressed by AGN feedback. We find that positive gradients (bluer stars at smaller radii) are typical for galaxies of $M_\star \sim 10^8$ Msun.

KEYWORDS galaxies, galaxy formation, galaxy structure

IAUS 373
#2815

Characterizing star formation in the innermost kiloparsec of the galaxy NGC 1386

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We characterize the star formation going on in the inner kiloparsec region of the galaxy NGC 1386 as derived from the analysis of a multiwavelength dataset covering the UV, optical, near-IR and mid-IR at subarsec resolution. We detect 61 point sources, distributed in a ring of 960 pc radius around the center of the galaxy. From SED fitting we conclude that these are low mass ($400 < M/Mo < 8000$) young clusters, with age distributed from 1 to 6 Myr, with a maximum at 4 Myr. Comparison of the Halpha luminosity of the clusters derived from the Halpha + [NII] narrow band image with that expected from the fitted ionizing continuum shows that a large fraction of the ionizing photons escapes from the clusters. Moreover, a large fraction of these photons escapes from the regions around the star forming ring.

KEYWORDS Star formation, young clusters, SED fitting, ionizing continuum, escape probability

IAUS 373

#2765

Quenching and boosting star formation in dwarf galaxies: the role of the environment

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Dwarf galaxies constitute the dominant population at all redshifts and they play a crucial role in the hierarchical build-up of galaxies, thus understanding their structure, formation, and evolution is a fundamental goal in astronomy and cosmology.

We present integral field spectroscopic (IFS) observations of a sample of star-forming dwarf galaxies (SFDG) in the Virgo cluster obtained with PMAS/PPak at the Calar Alto 3.5 meter telescope and atomic hydrogen (HI) observations taken with the GMRT telescope. The dwarfs are located in different regions of the cluster and present different star formation properties. In some cases the star-forming emission traced by the Hα line is centrally concentrated indicating that the cluster environment is gradually quenching the galaxies outside-in; in other dwarfs the asymmetry of the location of the star-forming regions and the presence of tails in the HI component suggest that ram pressure stripping is temporarily triggering star formation in the interface region between the interstellar and the intracluster medium. Moreover, some dwarfs present an enhanced star formation activity, indicating that gas accretion or, most likely, a dwarf-dwarf merger scenario may have occurred, as suggested by the evidence of inverted metallicity gradients in two galaxies of the sample (Grossi et al. 2020).

We analyse HI and Hα emission morphologies and velocity fields, and the metallicity profiles to better understand the stage of interaction of the dwarfs with the cluster environment and its effect on the quenching and boosting of the star formation process in dwarf galaxies.

We also compare the Virgo sample with SFDGs in the Fornax cluster for which archival IFS observations are also available. Fornax is less massive, more compact, and more dynamically evolved than Virgo, thus it is important to assess whether the differences between the two environments reflect on the star formation properties of their dwarf members.

KEYWORDS galaxy evolution, dwarf galaxies, interstellar medium, galaxy environment

IAUS 373
#2741

From evolved stars to the formation and evolution of galaxies

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Due to observational constraints, our detailed knowledge of stellar populations, formation and evolution of galaxies is limited to a few dozen galaxies located in Local Group. The local Group of galaxies offers a unique opportunity to construct the formation histories, and probe the structure and dynamics of many dwarf galaxies surrounding the Milky Way and Andromeda, and of isolated dwarf galaxies. In this regard, we monitored majority of galaxies in the Local Group including the M33 galaxy and satellites galaxies surrounding the Milky Way and Andromeda galaxy as well as isolated dwarf galaxies. We identified stellar populations and based on light curve analysis, the cool evolved stars pulsating in fundamental mode were identified. Then, a novel technique developed by Javadi et al. 2011 was used to derive star formation history (SFH) using the luminosity of these cool evolved stars. Surveying an entire satellite system enabled us to determine variations among satellites due to their infall histories, cosmic reionization, and internal processes, and to examine how these variations depend on their structural properties such as total mass, gas mass, and distance to their galaxy host.

In this paper, first I will present the results we obtained for SFH and dust production rate in individual galaxies separately to answer how different types of galaxies have been formed and evolved over cosmic time. Then, I will discuss whether the mass return from dusty evolved stars can provide enough gas reservoirs to sustain the star formation or even rejuvenate the dwarf galaxy, as some seem to harbour relatively young stars. Finally, I will compare the SFHs of different types of galaxies found in different environments to achieve a comprehensive picture of galaxy evolution in the Local Group.

KEYWORDS Local Group, galaxies: star formation, galaxies: stellar content, stars: mass-loss, stars: evolution

IAUS 373
#2687

Intrinsic dust and star-formation scaling relations in nearby galaxies

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Accurate dust and star-formation scaling relations are essential in studies of ISM evolution, star-formation and galaxy evolution studies, or related to the duty cycle of dust and gas in galaxies.

In connection with our recent work (e.g. Pastrav 2020, Pastrav 2021), we present results of a detailed analysis of a representative sample of nearby galaxies taken from the SINGS/KINGFISH survey, extended with a few similar low-redshift galaxies. The photometric parameters of the morphological components are obtained from bulge-disk decompositions, using GALFIT, with the surface photometry of the sample done beforehand. Dust opacities and dust masses are determined for the whole sample. Most of the measured parameters involved in these relations are affected by various systematic biases, such as dust and inclination/projection effects among others. The method and the library of numerical results for dust and projection effects, previously obtained, are used to correct the measured parameters to intrinsic (dust-free) values. Measured (observed) and intrinsic (corrected) galaxy dust and star-formation scaling relations are presented, in the optical regime, to emphasize the scale of the biases introduced by the aforementioned effects. To understand the extent to which star-formation is distributed in the young stellar disks of galaxies, star-formation connected relations with derived star-formation rates which rely on measurements of scale-lengths and fluxes or luminosities of narrow band images (such as those of Balmer lines), are also shown, both intrinsic and corrected.

The mean dust optical depth, the mean dust/stellar mass and dust/gas ratios of the sample are found to be consistent with values found in other studies of nearby galaxies. The main characteristics of the relations (e.g. slope, intercept - where necessary, scatter, correlation coefficients), are shown and discussed in comparison with values from other relevant studies in the literature.

KEYWORDS dust, galaxies, evolution, star-formation, relations

IAUS 373

#2694

Disk breaks as evidence for past star formation in the radial profiles of isolated galaxies

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In the standard cosmological model of galaxy evolution, mergers, interactions, and star formation play a fundamental role. Galaxies that are currently isolated are thus interesting: are they exceptional in not having experienced mergers, or did they merge and interact in the past and have since relaxed to appear isolated in the sky? To address this issue, we present the results of an extensive ultra-deep optical surface photometry observing campaign on the Isaac Newton Telescope, targeting a sample of 20 low-redshift ($z < 0.035$) isolated galaxies from the AMIGA project. The surface brightnesses achieved are unprecedented, reaching a level of ~31 mag arcsec^-2 in radial profiles through exquisite data processing and analysis techniques. This depth in the optical allows a delicate analysis of radial profiles, enabling the classification of breaks and truncations. It also allows the detection of the presence of stellar haloes. We identify the presence of minor mergers that have so far been undetectable even in the deepest publicly available optical surveys. Furthermore, we explore the different types of disk breaks (Type I ≡ single-exponential, Type II ≡ down-bending, Type III ≡ up-bending) as a function of the presence of tidal interactions, and in relation to ongoing star formation through comparison with UV imaging. Our work presents evidence of the cause of asymmetries in isolated galaxies.

KEYWORDS Galaxies: evolution, Galaxies: photometry, Galaxies: spiral, Galaxies: star formation, Galaxies: structure, Galaxies: enviroment

IAUS 373
#2691

Stellar Mass in Bars: Infrared Insights from the Local Universe

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Stellar bars are present in ~2/3 of nearby spirals and play a critical role in the evolution of their hosts. We exploit the Spitzer Survey of Stellar Structure in Galaxies (S4G) database to study the deepest mid-infrared imaging available for ~350 massive bars in the 3.6um and 4.5um IRAC/Spitzer bands. Based on the 2D decomposition of these images with the multi-band galaxy structure decomposition tool GALFITM, we translate stellar light to stellar mass associated to the primary bar in these systems. Considering that the mid-infrared represents the best single-band tracer of stellar mass in galactic structures, we use these results in an effort to provide a broad view of the stellar mass content typically contained in these ubiquitous structures. Preliminary results point to bars encompassing from a few percent to 30% of the galaxy's total stellar mass, with a typical value of 7%. We are initiating a similar study based on Illustris/TNG-50 simulations to compare the mass distributions of these structures as produced in state-of-the-art cosmological simulations.

KEYWORDS bars, mid-infrared, galaxy structures, 2D decomposition, observations, simulations

IAUS 373
#2684

Linking star formation thresholds and truncations in the thin and thick disks of the low-mass galaxy UGC 7321

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Thin and thick disks are found in most spiral galaxies, yet their formation scenarios remain uncertain. Whether thick disks form through slow or fast, internal or environmental, processes is unclear. The physical origin of outer truncations in thin and thick disks, observed as a drop in optical and near-infrared (NIR) surface brightness profiles, is also a much debated topic. These truncations have been linked to star formation (SF) thresholds in Milky-Way type galaxies, but no such connection has been made for their low-mass counterparts or in thick disks. Our photometric analysis of the edge-on galaxy UGC 7321 offers a possible breakthrough. This well-studied diffuse, isolated, bulgeless, ultra-thin galaxy is thought to be under-evolved both dynamically and in SF. It is an ideal target to disentangle internal effects in the formation of thick disks and truncations. Our axial light profiles from deep far- and near-ultraviolet (UV; GALEX) images, tracing recent SF, and optical (DESI grz) and NIR (Spitzer 3.6 micron) images, tracing old stellar populations, enable a detailed identification of an outer truncation in all probed wavelengths in both the thin and thick disks. After deprojecting to a face-on view, a sharp truncation signature is found at a stellar density of 1.5+-0.5 M_Sol/pc^2, in agreement with theoretical expectations of gas density SF thresholds. The redder colours beyond the truncation radius are indicative of stellar migration towards the outer regions. We thus show that thick disks and truncations can form via internal mechanisms alone, given the pristine nature of UGC 7321. We report the discovery of a truncation at and above the mid-plane of a diffuse galaxy that is linked to a SF threshold; this poses a constraint on physically-motivated disk size measurements among low-mass galaxies.

KEYWORDS Galaxies, Star formation, Thick disks

IAUS 373
#2623

Ubiquitous Dusty Star Formation in the Epoch of Reionization

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The evolution of galaxies has been mapped all the way back to the first few 100 million years after the Big Bang through large rest-frame ultraviolet and optical surveys. However, little is still known about how much star formation in the early Universe may remain hidden behind dust. Dedicated (sub-)millimeter observations are crucial in this regard, and have led to the surprising discovery of significant dust reservoirs in a handful of galaxies firmly established to lie in the epoch of reionization. Based upon these promising initial results, the Reionization Era Bright Emission Line Survey (REBELS) ALMA Large Program was carried out to systematically probe dust-obscured star formation and the interstellar medium through [CII] emission for 40 galaxies at $z>6.5$. In this talk, I will make use of the statistical sample provided by REBELS to show that typical galaxies in the epoch of reionization have a significant fraction of their star formation obscured by dust. In addition, I will present how this fraction depends on galaxy properties such as stellar mass and compare this to well-established relations at low redshift. Having demonstrated the ubiquity of dust in the epoch of reionization, I will use REBELS to construct the dust-obscured cosmic star formation rate density at $z\sim7$, and place this in the context of other observational studies and theoretical models to map out the history of star formation across cosmic time.

KEYWORDS Galaxy Evolution, High Redshift, Cosmic Star Formation, Interstellar Medium, Submillimeter

IAUS 373

#2545

Modelling Lyman-alpha emitters (LAEs) and properties of simulated LAEs: an empirical approach

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Lyman-alpha emitters (LAEs) are known to be young and active star-forming galaxies. LAEs allow us to investigate the properties of high redshifts galaxies($z > 2$) due to their strong Lyman-alpha emission line redshifted into a visible window. We model LAEs using 'Horizon Run 5 (HR5)', a cosmological hydrodynamical simulation in a volume of 1049 cMpc3. Specifically, we use a high-resolution zoom-in region with a volume of 1049*119*127 cMpc3 resolving ~ 1kpc from HR5. This modelling uses a probability distribution function of the rest-frame equivalent width of LAEs obtained from the relation between the equivalent width and the rest-frame UV magnitude in observations. We present the rest-frame UV luminosity functions at $z = 2$ - 10, and Lyman-alpha luminosity functions (LFs) at $z = 2.4$, 3.1, and 4.5. We also show various properties of the simulated LAEs over cosmic time ($2.4 < z < 4.5$), such as star formation rate, stellar mass, and host halo mass. Then, we compare the predicted LAEs from HR5 with the preliminary result of the ODIN (One-hundred-square-degree Dark energy camera Imaging in Narrowband) survey, a deep narrow-band survey aimed at identifying LAEs at $z = 2.4$, 3.1, and 4.5 with an unprecedented volume (91 deg2).

KEYWORDS high-redshift galaxy, Lyman alpha emitters, galaxy evolution, galaxy luminosity function

Conditions of giant molecular clouds in quenched lenticular galaxy NGC1387

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Molecular gas is key to our understanding of star formation and galaxy quenching. However, only over the past decade and with the capabilities of ALMA, spatially-resolved observations of giant molecular clouds (GMCs) beyond the Local Group have become widely feasible. NGC1387 is an early-type galaxy (barred S0) near the center of the Fornax Cluster. It has a molecular gas—rich nuclear disc within its bulge revealed by ALMA CO(2-1) observations at 15 pc resolution. We have identified 1592 individual GMC and measured their properties (radius, velocity dispersion, gaseous and dynamical mass, etc). We have found NGC1387 GMCs follow very similar scaling (e.g. Larson) relations as GMCs in the Milky Way disc, which is still forming stars. Also, the GMCs are perfectly Virialised, which means they are gravitationally bound and tend to collapse. Thirdly, the gas fraction and Toomre instability parameter of the gas disc both indicate potential star formation. Despite these properties, NGC1387 is far from the star-forming main sequence as shown by VLT/MUSE data. We discuss possible reasons behind the discrepancy between GMC properties and the lack of star formation in this galaxy.

KEYWORDS giant molecular cloud, molecular ISM, galaxy quenching mechanism

IAUS 373

#2380

The formation of the Brightest Cluster Galaxy and Intracluster Light in cosmological N-body simulations with the Galaxy Replacement Technique

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To describe the formation of low surface brightness (LSB) structures in/around galaxies, we develop an efficient numerical technique named Galaxy Replacement Technique (GRT) that replaces a low-resolution DM halo with a high-resolution galaxy, composed of a DM halo and stellar disk. We perform the GRT simulation targeting the six clusters with high-resolution particles of mstar ~ 5×104 h-1M$_\odot$ to describe the tidal stripping of member galaxies. We investigate the formation channel of the Brightest Cluster Galaxy (BCG) and Intracluster Light (ICL) as a function of the dynamical state of the clusters and distance from the center of the clusters.

KEYWORDS Low surface brightness, cosmological simulation, Galaxy Replacement Technique, galaxy cluster, Intracluster Light, Brightest Cluster Galaxy

AstroTalk project: Inclusion and intercultural aspects of Astro-Tourism activities: Astro Camping Project in Djerba: The First step to develop Astronomy in Tunisia

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Tunisia is a country located in the North of Africa, on the coast of the Mediterranean Sea, and also on the edge of the Sahara desert, where tourism represents one of the most important sources of income. It sports a glorious history and exceptional natural beauties since it is reached in archaeological remnants, ranging from Roman mosaics to Arabic art displayed in several Museums and in breathtaking locations. The mild climate of its coasts facing the Mediterranean Sea and the sharp contrast of the fascinating desert of its internal southern regions, together with a relatively low cost of living, make

Tunisia is a preferred touristic destination. Moreover, the southern regions present very favorable conditions for astronomical observations because of the long periods of clear skies and the light pollution is fortunately still very low. Furthermore, many sites are going to be proposed as possible locations for future astronomical observatories.

Unfortunately, up to date, Astronomy and also any related field, are still absent in Tunisian Universities, in addition, they are no academic astronomical Observatories or dedicated professional instruments for this field of science. However, there are several telescopes used in the context of cultural and associative activities and for general public events, and here comes the role of these activities in presenting the importance of astronomy in developing the quality of education and society. In this work, we are proposing the Astro-Camping project in Djerba, as an initiative to share the astronomical culture and help to develop the study of astronomy in Tunisia.

KEYWORDS archaeological, Museums, Astro-Camping, Observatories, culture, southern, tourism

IAUS 373

#2251

Star formation history and possible LGRB hosts

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IllustrisTNG is a suite of large volume, cosmological, gravo-magneto-hydrodynamical simulations including a comprehensive model for galaxy formation. Each TNG simulation self-consistently solves for the coupled evolution of dark matter, cosmic gas, luminous stars, and supermassive blackholes from redshift z=127 to 0, and generates 100 resulting snapshots from z=20 to 0. We used the TNG100 run for analysis, which has the size of 110.7^3 Mpc^3 and contains more than 10 billion resolution elements.

We processed the catalogue data for all snapshots of the TNG100 run to statistically analyze the properties of galaxies at each redshift. This gave us a unique view of how galaxy properties evolve at cosmic time scales, and how different properties relate to star formation. The imprint of large-scale cosmic events could also be seen on the evolution of the star formation rate.

For comparing the simulated results with observations at higher redshifts we constructed a sample of possible LGRB host galaxies from the catalogue data using current models. Comparing this simulated sample to observational samples allowed refining the models and provided an insight on higher redshifts. Comparing the simulated LGRB host sample to all simulated galaxies could highlight differences in the properties of star forming galaxies.

KEYWORDS galaxies: star forming, galaxies: distances and redshifts, cosmology: large-scale structure of Universe, galaxies: formation and evolution, methods: statistical

IAUS 373
#2179

Reconstructing the Star Formation History of M31 Galaxy Using Evolved Stars

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The rate of star formation (SFR) is one of the important quantities that help to study galaxies' evolutionary path. In fact, measuring the SFR during the life of the universe shows us how galaxies have acquired their metallicity and star mass. In this regard, the galaxies of the local group give us the great opportunity to study the connection between different stellar populations and galaxy evolution. In this paper, we use the Long-Period variable stars to estimate the star formation history in the M31 galaxy. These stars are powerful instruments to achieve this goal. They reach their peak luminosity and coldest state at the final point of their evolution also there is a directly related between birth mass and their luminosity so using stellar evolution theoretical models, we construct the mass function and hence the SFH.

KEYWORDS AGB stars, Galaxies, evolution, star formation, luminosity function, mass function, M31

IAUS 373
#2166

Residual Star Formation in z~1 Quiescent galaxies observed in UVCANDELS

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The classical early/late-type galaxy dichotomy is increasingly less well-defined at higher redshift, when different epochs of galaxy assembly and evolution are probed than in the local universe. Using new rest-frame UV imaging obtained by the UVCANDELS HST Treasury Program in CANDELS deep fields (GOODS-N, GOODS-S, EGS, and COSMOS) we identify a sample (N~400) 0.5<z<1.5 massive (log(M)~10.5) quiescent galaxies. We combine the new UV photometry with archival imaging and spectroscopy to measure the size evolution of these galaxies, their star formation histories, and the relative richness of their local environments. We find a size growth, at a fixed stellar mass, of ~2x over the redshift range probed, in agreement with previous surveys at this redshift. Though these galaxies were selected as quiescent (i.e., effectively devoid of significant recent star formation) using UVJ color-color criterion, the long baseline in UV wavelength coverage now available for these galaxies reveals that ~15% of this sample experienced a burst of recent star-formation (t<1Gya, M_burst/M_stellar~10^-3). In addition, we find a weak statistical correlation between the richness of the local environment for quiescent galaxies and the presence of young stars. We interpret these observed trends as an indication that the establishment of the quiescent galaxy population is relatively extended in time (from z~4 to the current epoch) and is punctuated by periodic wet, minor mergers. These mergers act to "grow" early-type galaxies from their compact sizes at the formation redshift, while delivering cold gas which may lead to a burst of star-formation, the characteristics of which can be uniquely studied with the UVCANDELS survey imaging at z~1.

KEYWORDS Quiescent Galaxies, Star Formation in Massive Galaxies, Early Type Galaxies

IAUS 373
#2142

Resolved Molecular Gas Observations of MaNGA Post-starbursts Reveal a Tumultuous Past

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Post-starburst galaxies (PSBs) have recently and rapidly quenched their star-formation, making them an important population for understanding the processes that cause galaxies to transition from star-forming late-type galaxies to quiescent early-type galaxies. However, the recent discovery of large cold gas reservoirs in PSBs calls into question the theory that galaxies must expel or exhaust their gas to become quiescent. To better understand the mechanisms that quench star formation, we analyze a sample of 14 nearby ($z < 0.1$) PSBs with spatially resolved optical IFU data from the MaNGA survey and with matched resolution ALMA observations of 12CO(1-0). This unique sample allows us to study the molecular gas and star-formation properties on kpc scales and increases the total number of PSBs with resolved gas measurements by a factor of 3. We find centrally concentrated molecular gas morphologies, with ~75% of the molecular gas contained within 3-sigma of the beam size, on average. We also see a diversity in the alignments of the kinematic axes of the stellar, ionized and molecular gas components, which depend on whether the post-starburst spaxels are centrally concentrated. We compare the molecular gas and star-formation rate surface densities of the post-starburst regions of galaxies in our sample to other star-forming galaxies and PSBs and find that star-formation tends to be suppressed in our PSBs with central post-starburst regions in particular. While the post-starburst regions in some of our galaxies are gas-poor with typical star-formation efficiencies, others display typical star-forming gas fractions with greatly reduced star-formation efficiencies. Overall, our results point to a major event disrupting the gas in these post-starbursts, driving it inwards and resulting in centrally concentrated gas reservoirs with varied kinematics that form stars at a suppressed rate.

KEYWORDS Galaxy evolution, Galaxy quenching, Post-starburst galaxies, Molecular gas

IAUS 373
#1916

The density structure of molecular cloud scales: A fitting for N-PDF with multi log-normal functions

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Molecular clouds are an important evolutionary stage in star formation scenarios, containing both dense regions directly linked to star formation and diffuse regions. The density structure of molecular clouds is formed by the influence of physical processes such as turbulence, self-gravity, and massive star feedback. We performed a study of the hierarchical density structure of molecular clouds using data from the Nobeyama 45-m Cygnus X CO survey. Using the DENDROGRAM and SCIMES algorithms, we identified a total of 124 molecular clouds in 13CO data. Of these identified molecular clouds, the H2 column density probability distribution function (N-PDF) were constructed for 11 extended (> 0.4 deg2) molecular clouds. From the fitting of the N-PDF, we find that the N-PDF can be well fitted with one or two log-normal distributions but no power-law distributions at the high-column density part. These fitting results provide an alternative density structure of molecular clouds from conventional.

We investigated the column density, dense molecular cloud cores and radio continuum sources distributions in each cloud, indicating that the N-PDF shape has less correlation with the star-formation activity and the morphology of molecular clouds. Furthermore, we found that the log-normal N-PDF parameters obtained from the fitting show two impressive features as follows. First, the log-normal distribution at the low-density part has the same mean column density (~ 1021.5 cm-2) for almost molecular clouds. Second, the width of the log-normal distribution showed a tendency to narrow with an increasing mean density of structures. These correlations suggest that the shape of the N-PDF reflects the relationship between the density and turbulent structure of the molecular cloud and may not be affected by the star-forming activities.

KEYWORDS ISM: clouds, ISM: structure, ISM: molecules, stars: formation, methods: analytical

IAUS 373
#2093

Sub kpc-scale gas density histogram of the Galactic molecular gas: a new statistical method to characterise galactic-scale gas structures

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To understand the physical properties of the interstellar medium (ISM) in various scales, we should investigate it with pc-scale resolution over kpc scale coverage. Here, we report the sub-kpc scale Gas Density Histogram (GDH) of the Milky Way. GDH is a histogram of averaged density and corresponds to the probability density distribution function (PDF) of gas volume density. We use galactic plain survey data (l=10deg-50deg) at 12CO, and 13CO (J=1-0) obtained as a part of the FOREST Unbiased Galactic plane Imaging survey with the Nobeyama 45m telescope (FUGIN), which is a legacy project of the Nobeyama 45-m telescope. With this method, we are free from spatial structure and molecular cloud identification. We made a GDH of 2 deg by 2 deg area without setting the cloud boundary but included the blank sky component in observed GDH; it is different from the previous PDF works for molecular clouds. After subtraction of the blank sky component, the resultant GDH can be well fitted with single or double log-normal distribution; which we call as the low-density log-normal (L-LN) and high-density log-normal (H-LN) components. We found both the ratio of total volumes of L-LN and H-LN components and L-LN width along the gas density axis show a coherent structure on the longitude-velocity diagram. It suggests that there is a relationship between the ISM property and kpc scale structure in the Milky Way.

KEYWORDS ISM structure, galactic structure

IAUS 373
#2048

Star formation feedback onto molecular clouds of KAGONMA objects using temperature distribution

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The effects on the interstellar matter (ISM) by star formation, i.e. the star formation feedback, is critical to understand the evolution of galactic eco-system. To approach this issue, emission from ammonia molecules is powerful. Because of many emission lines in the narrow frequency band at 23 GHz, it gives us physical quantities such as optical thickness and temperature only with simple assumptions. However, most of previous studies in ammonia were made only single point observations of molecular cores. Therefore, we have conducted a mapping observation project, named KAGONMA (KAgoshima Galactic Object survey with the Nobeyama 45-meter telescope by Mapping in Ammonia lines), to figure out the regions affected by star formation activities. The star formation feedback is expected by expansion of an HII region, bipolar outflow and intense radiation, which produce shock waves and heat up the surrounding gas. As a prelude of KAGONMA, we observed the Monkey Head Nebula (Chibueze+2013) and other clouds (e.g. Burns+2019, Kohno+2022). In this talk we present the current status of KAGONMA including the results of several objects. KAGONMA targets were selected based on C18O (J=1-0) emission line data obtained by FUGIN (FOREST Unbiased Galactic plane Imaging survey with the Nobeyama 45-meter telescope) and made as one of common use observation projects with Nobeyama 45-meter telescope. In some objects we found a warm (about 20 K) region associated with a compact HII region but its size is in the order of 1 pc and no evidence of direct star formation feedback in other part of the cloud. This suggests that the direct star formation feedback is very limited spatially in a molecular cloud.

KEYWORDS ISM, HII region

IAUS 373

#2014

A cloud-scale view of the star formation process in nearby galaxies

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Where do stars form and how is their formation regulated across galactic disks are two critical questions for our understanding of the star formation process. High angular observations of nearby galaxies allow us to sample the star formation process across entire galactic disks reaching now regularly the scales of the star-forming units, namely Giant Molecular Clouds (GMCs) and HII regions. Such data are ideal to resolve the gas-star formation cycle, provide new insights on the molecular gas reservoir and its role in the star formation process, and assess the importance of galactic components such as bulges, stellar bars, spiral arms and active galactic nuclei (AGN) in the conversion of cold (molecular) gas into stars. I will introduce the PHANGS (Physics at High Angular resolution in Nearby GalaxieS) survey and present a few highlight from the ongoing research of the collaboration.

KEYWORDS star formation process at cloud-scales, nearby galaxies

IAUS 373

#812

Collision-induced formation of dark-matter-dominated galaxies and dark-matter-deficient galaxies

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The standard galaxy formation model predicts that galaxies form within a Cold Dark Matter (CDM) halo and that galaxies are dominated by dark matter. However, recent observations have discovered dark-matter-deficient galaxies with much less dark matter mass than theoretical predictions, and the process of their formation has been discussed. Here, we investigate the physical processes of galaxy formation by collisions between gas-rich dark matter subhalos (DMSHs) within the context of the CDM paradigm. Prior to a numerical simulation, we analyze a bifurcation between the formation of dark-matter-dominated galaxies and dark-matter-deficient galaxies, corresponding to the collision velocity of DMSHs moving in a host halo. In the case of low-velocity collisions, a dark-matter-dominated galaxy is formed by the merging of two DMSHs. In the case of moderate-velocity collisions, the two DMSHs penetrate each other, but the gas medium collides, forming a dwarf galaxy without dark matter at the collision surface. Shock-breakout occurs due to the shock waves generated at the collision surface reaching the gas surface, and there is no galaxy formation in the case of high-velocity collisions. Then, we simulate head-on collisions between DMSHs with the same mass in the range from 107 Msun to 1010 Msun. The results show that dark-matter-deficient galaxies with total masses ranging from 107 Msun to 109 Msun are formed from the colliding gas with 0.1 solar metallicity under the collisional ionization equilibrium, depending on the mass of DMSHs and the collision velocities. Finally, we estimated the probability distribution of relative velocities between colliding subhalos under the well-relaxed host halo to examine the efficiency of the formation of a dark-matter-deficient galaxy. A result shows the collision velocities satisfy the critical condition of forming a dark-matter-deficient galaxy within 0.1 virial radii of the host halo except for the central region.

KEYWORDS galaxies: evolution, galaxies: formation, galaxies: interactions

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IAUS 373
#2006

Revealing the Relation between Star Formation Activity of Jellyfish Galaxies and Ram-pressure Stripping

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Ram-pressure stripping (RPS) is known as the most efficient mechanism for quenching the star formation (SF) activity of gas-rich galaxies in clusters. However, RPS can also trigger SF in galaxies by compressing the gas within a few hundred Myr. Jellyfish galaxies show a snapshot of the SF enhancement of galaxies undergoing RPS, exhibiting blue star-forming knots in their disks and tails. They are very unique and important targets to investigate the SF activity in relation to RPS. We explore the relation between SF activity and the RPS of jellyfish galaxies, using 5 jellyfish galaxies studied with our GMOS/IFU observations. Their host clusters are massive (M200 ≥ 1015 $M_{\odot}$) and X-ray luminous (log LX ≥ 44.5 erg s-1), implying that these jellyfish galaxies are subject to much stronger RPS than those in low-mass clusters. Thus, we compare their SF activity to that of jellyfish galaxies in other hosts with a wide range of virial mass, including the low-mass clusters of the GAs Stripping Phenomena (GASP) survey, A901/2 supercluster (z=0.17), and A1758N (z=0.28). In the SFR-M* diagram, our sample and A1758N jellyfish galaxies in massive clusters show higher SFR excess relative to the star formation main sequence compared to the GASP and A901/2 samples in low-mass clusters. These results imply that the SF activity of jellyfish galaxies is strongly enhanced by extreme RPS in massive clusters. Thus, we find that the SF activity of jellyfish galaxies has positive correlations with the cluster velocity dispersion and the degree of ram pressure, which has not been shown well in the previous studies.

KEYWORDS Jellyfish galaxy, Starburst galaxy, Ram-pressure stripping, Integral field spectroscopy, Star formation

IAUS 373
#2005

Volumetric star formation law in the almost edge-on galaxy NGC 4302 vertically resolved by ALMA

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We investigate the volumetric star formation law (SFL) using the almost edge-on galaxy NGC 4302 (i~90 degree) observed by ALMA (CO), VLA (HI), KPNO (H-alpha) and Spitzer (24 micron). We measure the scale heights of CO, HI, and the star formation rate (SFR) that increase significantly as a function of radius and infer their volume densities. We compare the SFR with the molecular gas (H2), the atomic gas (HI), and the total gas (H2+HI) based on volume densities and find tight power-law correlations between the SFR and the gas (HI, H2, and HI+H2) densities. The power-law indices of the volumetric SFL are noticeably smaller than the indices of the surface SFL, except for the molecular gas, whose indices for the volumetric and surface SFLs are similar to each other. The volumetric star formation efficiencies (SFEs) for the molecular and total gas are fairly constant, while the SFE for the atomic gas decreases as a function of radius. We find that the volumetric SFE is quite lower than the surface SFE in the H2 dominated regions.

KEYWORDS edge-on galaxy, NGC 4302, ALMA, ISM, star formation law, kinematics, structure

IAUS 373

#2002

The star formation history and transition epoch of the cluster galaxies based on the Horizon-AGN simulation

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It is observationally well established that the galaxies in dense environments are more star-formation quenched. But theoretically, it is not difficult to imagine that the clusters were the sites of more active star formation in the early Universe. Then, when did the transition from ``active" to ``passive" occur in cluster galaxies? What effects did galaxy mass have on it? We hereby present an interpretation based on the large-scale cosmological hydrodynamic simulation Horizon-AGN.

We find that massive galaxies in general have small values of e-folding timescales of star formation (i.e. ``mass quenching'') regardless of their environment. Whereas, low-mass galaxies show more prominent environmental dependence. In massive host (i.e. cluster) halos, the e-folding timescale of low-mass galaxies could be reduced and decreased further if they reside in those halos for a longer period of time.

Furthermore, we define the ``transition epoch'' at which cluster galaxies become less star-forming than field galaxies. The transition epoch of satellite galaxies is varied by their stellar and host halo masses. While the lowest-mass satellites in the most massive clusters show the earliest transition epoch of ~ 8 Gyr in lookback time in our sample, it decreases to ~ 6 Gyr in low-mass group halos or for massive satellites.

In this sense, the present ratio between the stellar mass and the cluster halo mass can be a tracer to the entire star formation history of satellite galaxies.

KEYWORDS Galaxy, Galaxy Cluster, Star formation history, Environment, Quenching

IAUS 373
#1992

Neutral hydrogen observation of the complex extraplanar filamentary network in NGC2403

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One important open question in galaxy formation and evolution is how they sustain the current star formation rate of ~1 solmass/yr while showing a constant HI mass. Indeed, HI accretion phenomena due to merging events and tidal interactions between galaxy might account only a fraction of the needed gas. It is thought that the main source of HI is the intergalactic medium, although no direct evidences of cosmic accretion flows, nor the modes in which this process might happen, have been discovered yet. The main limitation is the sensitivity-resolution combination of the current radio telescopes (e.g., VLA, WSRT). We tried to work around this boundary by combining many observations of the same object and so virtually increase the observing time (hence lowering the detection limit while maintaining a sufficient angular resolution). NGC 2403 is a nearby galaxy with a high number of VLA observations and evidences of a disturbed HI distribution probably related to accretion events. For the first time all the main available dataset have been combined together to obtain a single virtual long-exposure observation. Our new data revealed the presence of a complex population of different HI features (filaments and clouds) with a total HI mass of the order of 10% of the galaxy. The absence of clear galactic companions in the proximity of NGC 2403 might potentially rule out the merging or tidal interaction origin of this anomalous HI, although it might be the remnant of an ancient event. Furthermore, the spatial extension and distribution of these features are challenging to explain in the galactic fountain scenario. Consequently, we conclude that they are likely the final stage of the cosmic accretion flow onto NGC 2403.

KEYWORDS Radio astronomy, Galaxy evolution, Neutral hydrogen, Gas accretion

IAUS 373

#1957

The Evolution of Star-Forming Sequence and Quiescent Fraction of Simulated Galaxies and in CANDELS at z=0.5-3.0

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We present a consistent comparison of the evolution of the Star-Forming Sequence (SFS) and the fraction of quiescent galaxies in the Illustris, EAGLE, IllustrisTNG, and SIMBA hydrodynamic simulations and the Santa Cruz semi-analytic model, alongside observed data from the HST CANDELS survey. We use Gaussian mixture modeling, a flexible data-driven approach to identify the SFS over a wide range of star formation rates and stellar masses, in 6 different redshift bins from z=3 to z=0.5. We find that the slope and normalization of the SFS in simulations are overall consistent with CANDELS observations in all redshift ranges. The longstanding SFS normalization offsets of 0.2-0.5 dex between models and data at high-z are resolved when we use the updated masses and SFRs of CANDELS galaxies from the SED fitting method that reconstructs smooth and non-parametric star formation histories. The fraction of quiescent galaxies in simulations and observation shows the same redshift trend but varies widely. There is little consensus for the quiescent fraction even at high-z, where we find good agreement among the SFSs.

KEYWORDS Star formation, star formation main sequence, quenched fraction, quiescent fraction, simulations, high-redshift

IAUS 373
#1912

From CO Emission to Molecular Gas - How Differential Excitation of CO Lines Impacts the Sub/millimeter Observational Frontier

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The J=1-0 transition of the CO line has long been the canonical tracer of molecular gas. However, the improved sub/millimeter facilities, the push for higher resolution, and a growing interest in high redshifts all favor observations with the higher frequency CO(2-1) line. Recent studies have found evidence that CO(2-1)-CO(1-0) line ratios vary between galaxies of different types and across galactic environments, suggesting that care is needed when interpreting CO(2-1) as a tracer of bulk molecular gas. These results are complicated considerably by the difficulty of comparing millimeter data collected with different facilities. Calibration issues produce systematic uncertainties comparable to the dynamic range of trends found in recent studies and resolved measurements can produce contradictory results depending on the datasets used. I will present the Arizona Molecular ISM Survey with the SMT (AMISS), a multi-CO line survey of ~200 nearby galaxies designed to understand CO line ratios across a broad range of galaxy properties. AMISS uses data from a single telescope for each line, with careful attention to calibration, which allows us to overcome many of these difficulties. The large size of our survey allows us to identify trends between galaxy properties and CO line ratios. In particular we find a correlation between CO(2-1)/CO(1-0) and galaxy-integrated star formation rate. This effect propagates to the slope of the Kennicutt-Schmidt relation, giving different slopes for measurements made with different lines. I will discuss how these results impact the interpretation of CO(2-1) studies at high and low redshifts, and motivate the need for resolved, multi-CO line surveys of larger samples of galaxies.

KEYWORDS Galaxies, ISM, Molecular Gas, Radio Astronomy, Star Formation

IAUS 373

#1896

Assembly of a rotationally supported star-forming galaxy at z ~ 7

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Studies of the ultraviolet distribution of high-redshift galaxies indicate that the early stages of galaxy formation involve disturbed and clumpy systems. In recent years, the study of these galaxies has been revolutionized by the advent of ALMA, by accessing the complex process of mass assembly through the observations of the cold gas morphologies and kinematics. It has been yielding increasing evidence of the existence of rotationally supported disks at z~7. Although there is already a significant number of objects being studied via [CII] line emission, it is still necessary to further deepen our understanding of the internal structures of these galaxies through sensitive high-resolution observations.

In this presentation, I will show results of a detailed study of a massive star-forming galaxy COS2987 at z=6.8. In previous studies, the galaxy showed tentative signs of being a system supported by rotation, which is a rare case for galaxies in the middle of the reionization period. Our new high-resolution [CII] line imaging with ALMA allows us to spatially resolve the galaxy and dissect the three dimensional [CII] line emission (space + velocity) and thus understand their morphology and dynamical state.

Through modeling of the velocity distribution (using 3DBarolo) we confirm a rotationally-supported nature for this galaxy and observe a co-spatial distribution of the UV and [CII] emission within the main disk. We identify the presence of interesting features, indicating a scenario of satellite accretion. However, we did not identify an extended halo structure as found in recent studies, showing that such structures are not ubiquitous in high-z galaxies. Future deeper observations of ionized gas with ALMA and JWST will yield key evidence for the reality of the faint structures, and will inform the accretion mechanisms already in place in the first galaxies in the Universe.

KEYWORDS high-redshift, ISM, star-formation, structure, kinematics

IAUS 373

#1874

Environmental Coping Mechanisms that Sustain Star Formation at Low Metallicities in Dwarf galaxies

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Despite the challenges the Star Formation (SF) process is facing in low metallicity environments, Star Formation takes place all the same. In these environments, the molecular gas may be dark and the CO cores small, the metal content may be insufficient to sustain dust-shielding, yet Star Formation takes place all the same. How can that be? We suggest that in the low metallicity environments of Dwarf galaxies different coping mechanisms are at play to compensate for the insufficiencies of the environment and sustain Star Formation. We discuss three types of coping mechanisms: HI enveloping of the molecular cores to compensate for inefficient dust-shielding with self-shielding, existing stars contributing positively to the local environment of future SF sites and bar activity as a SF enhancer. According to the recent results of Querejeta et. al., 2021 within the bar region of the PHANGS sample (Leroy et al., 2021) of barred galaxies, star formation is enhanced. We further study this enhancement mechanism and the possibility that the bar conducive to high intensity star formation may induce a higher molecular gas content in the bar region, one that raises above the current molecular gas detectability limits in Dwarf galaxies. Hence, the study of such coping mechanisms not only helps us gain a deeper understanding on star formation at low metallicities, but also provides means to push some of the current observational and detectability limits.

KEYWORDS Star Formation, Dwarf galaxies, Low metallicity

IAUS 373

#1872

Controlling stellar mass scatter through black hole mass and AGN feedback

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The galaxy--halo connection is a fundamental bridge between observations and theory that supports our understanding of the underlying physics of galaxy formation. Generally, empirical models map the stellar mass of galaxies to halo masses from n-body simulations to create a mean stellar mass-to-halo mass relation (SMHMR) that can be used to calibrate physical models. However, the scatter in this relation is not well understood. Empirical models have not been able to fully constrain this scatter. In addition, semi-analytic models (SAMs) systematically predict higher stellar mass scatter at fixed halo mass than hydrodynamical simulations. Our goal is to investigate the physical origin of this scatter by exploring modifications to the physics in the SAM {\sc Dark Sage}. Our experiments show that, a) scatter in the black hole mass at fixed galaxy mass, and b) the aggressiveness of the AGN feedback mechanism, have the greatest effect on scatter in the SMHMR. Changes to the black hole seeding mechanism have less of an effect.

KEYWORDS galaxy formation and evolution, galaxy-halo connection, black hole physics, AGN feedback, semi-analytic model

IAUS 373
#1809

The History of Metal Loss via Stellar Feedback-Driven Outflows from the Massive Spiral Galaxy M31

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Following episodes of star formation, massive stars inject metals, energy, and momentum into their surroundings and can drive galaxy-wide outflows of metal-enriched gas. How this stellar feedback shapes galaxies over cosmic time is encoded in their present-day metal content. Here, we present novel constraints on the cumulative impact of feedback-driven outflows on the evolution of the nearby, massive spiral galaxy M31. Resolved-star photometry across ~1/3 of M31's disk obtained by the Panchromatic Hubble Andromeda Treasury (PHAT) survey enabled high-quality measurements of spatially resolved star formation and enrichment histories. We use these measurements from PHAT to calculate the metal mass locked into stars, and additionally use the gas-phase metallicity gradient and maps of dust and neutral hydrogen to conduct a census of the metals currently present in the PHAT footprint. The history of metal production in the same area is calculated by combining the star formation histories with a model of metal production by supernovae and AGB stars. We find that 62% of the metal mass has been lost from the disk via outflows, and that metal loss is required under any model assumptions. Metal loss from M31 must have occurred before redshift 1, when the galaxy's star formation rate was significantly higher than it is today. Finally, we show that metals produced in the last 1.5 Gyr have been redistributed within the galaxy, hinting that low-level, ongoing star formation is driving a galactic fountain process in M31's disk. Comparing the observed fraction of metals retained in galaxies to the predictions of galaxy formation models is a promising path to quantify the impacts of feedback from star formation on galaxy evolution.

KEYWORDS

IAUS 373
#1808

Constraints on primordial magnetic fields from high redshift quasars

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Magnetic fields are known to permeate galaxies, yet their origin is unclear. A likely explanation is that magnetic fields grow from a seed field through a dynamo, where the seed field is either a relic of inflation or due to turbulence in the interstellar medium during structure formation. Optical emission lines in the spectra of luminous quasars provide a window into physical conditions, such as magnetic fields and shock velocities, in the regions surrounding supermassive black holes. At early cosmic times which provide the strongest constraints on seed fields, the characterization of these conditions is a challenge since key diagnostics emission lines are redshifted in the observed near/mid-infrared wavelengths. In this study, we show for the first time, that typical indicated magnetic field strengths in distant quasars at z~5.9 exceed 6 μG. This is similar to that estimated for some of the most luminous active galactic nuclei in the local Universe. Our measurement implies that strong, coherent magnetic fields were present in the interstellar medium at a time when the universe was < 1 billion years old. Comparing our estimated magnetic field strengths with models for the evolution of galaxy-scale fields, favors high seed field strengths exceeding 0.3μG, the first observational constraint on such fields. This high value favors scenarios where seed magnetic fields were produced by turbulence in the early stages of galaxy formation.

KEYWORDS Quasar, galaxy formation, high-redshift, galaxy evolution, infrared

IAUS 373
#1786

Jellyfish caught in the Webb: Probing environmentally-triggered star formation with JWST

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Enhanced star-formation in morphologically-disturbed cluster galaxies, such as the so-called "Jellyfish", can be triggered by large-scale processes including cluster mergers. The blue "tails" of these beautiful galaxies are sometimes seen to be orientated in the direction of the dynamical axis of the cluster merger, as expected of material stripped by the extreme ram pressure of the passing cluster-scale shock. While available photometry is adequate to estimate total star-formation rates for galaxies in intermediate-redshift clusters (combining e.g. GALEX+Herschel UV+FIR), the next step is to explore the evolution of their different morphological components, and locate any low surface brightness stripped material. After 6 months of commissioning, the space-based infrared IFUs installed as part of James Webb Space Telescope's NIRSpec and MIRI science instruments will now begin to provide a unique spatially-resolved perspective, with a field-of-view well matched to the few arcsec size of these Jellyfish. For the first time, we will be able to characterise the atomic gas, stellar populations and obscured star-formation in different regions of individual Jellyfish galaxies. In this presentation, I summarise our current knowledge of these fascinating tracers of the dynamic cluster environment, as well provide an insight into the upcoming prospects with JWST.

KEYWORDS JWST, Jellyfish, IFU, Galaxy, Cluster

IAUS 373
#1762

The ALPINE-ALMA [CII] survey: dust attenuation curves at z=4.4-5.5

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There is now ample evidence that dust is already present at high redshift. Even if it represents but a tiny fraction of the mass of the interstellar medium, dust has a strong effect on the emerging radiation, dimming and reddening it. However, given the faintness of distant galaxies in the optical and the near-infrared, datasets are still limited and how exactly the dust affects the emission of galaxies at very high redshift is not yet fully understood. This has direct consequences on our ability to obtain unbiased measurements on some fundamental physical properties of galaxies such as their stellar mass or their star formation rate. One of the major uncertainties is the shape of the attenuation curve. Important variations in the slope have been found both from models and observations up to intermediate redshifts. Whether this extends to higher redshifts is uncertain. In this communication, we will present new results based on a panchromatic analysis of 23 main-sequence galaxies at z=4.5-5.5 from the ALPINE survey. Using the CIGALE modeling code, we find that the attenuation curves span a broad range of properties, from curves that are much steeper than the SMC extinction curve, to shallower than the starburst attenuation curve. The steepness of such curves is probably the consequence of the combination of the combination of several physical processes. The broad range of attenuation curves found at z~5 shows that no single attenuation curve is appropriate for main-sequence galaxies and that assuming a fixed curve can lead to large errors, for instance in the interpretation and use of the IRX-beta diagram. We will conclude discussing the practical impact of this variability on the measurement of the stellar mass and the star formation rate of distant galaxies.

KEYWORDS high-redshift galaxies, dust, SFR measurements

IAUS 373
#1746

Cold gas accretion and removal in NGC 1566 and their implications for its star formation history

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The star formation (SF) history of a galaxy is regulated by the availability of its cold gas, which in turn is driven by the balance between material accreting from intergalactic space and gas expelled from the galactic disk. Atomic neutral hydrogen (HI) is an excellent tracer of this process. Nevertheless, past HI observations have always been limited by a trade off between field of view, spatial resolution and sensitivity, preventing studies of the very faint HI gas from the inter-galactic environment, as well as the very compact sub-kpc HI distributions within the main disk and its link with SF regions. The MHONGOOSE large survey of MeerKAT is bringing the study of the HI in nearby galaxies (< 30 Mpc) to the next level: thanks to deep (55 hours) high spatial (>6'') and spectral (1.4 km/s) resolution observations over a wide field of view (1.5 degrees), we are able to identify and study the kinematics of the HI gas in star forming galaxies down to M(HI)=10^5 Msun for individual clouds and low column densities ~2x10^18 cm-2 (3sigma detection limit at 30'' with a linewidth of 5 km/s). In this talk, I will focus on the interaction history of the massive (M(HI) 10^10 Msun) star-forming face-on galaxy NGC1566 (DL=18 Mpc) and the impact on its SF. For the very first time, the MHONGOOSE observations identify that a past tidal interaction with a massive companion (NGC1581) has left several gaseous debris clouds in the environment. The low-column density (<10^17-19 cm-2) HI filaments connecting the disk of N1566 with nearby dwarf galaxies (M(HI) 2x10^6 Msun), suggest that more minor interactions are still on-going, actively contributing to the accretion of HI onto the galactic disk, as well as to gas removal from its outskirts. By resolving the HI clouds throughout the spiral arms of NGC1566 and comparing their distribution and kinematics with the molecular and ionised gas we gain new insights on the triggering and fuelling of SF in the disk of late type galaxies.

KEYWORDS NGC1566, ISM, Neutral hydrogen, MeerKAT, environment, Star Formation

IAUS 373
#1736

Galaxies in clusters: co-evolution of the dark and baryonic components

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Galaxy clusters are large structures in the Universe, composed of tens to hundreds of galaxies bound by gravity. Due to their very high mass density, there are specific processes that take place within them, and shape the properties of their component galaxies (harassment, starvation, ram-pressure stripping, ...), as well as of their associated dark matter subhaloes (dynamical friction, tidal stripping). In particular, galaxy clusters are very efficient at quenching the galaxies that compose them, and are therefore responsible for the quenching of a significant fraction of the total passive galaxy population, especially in the lower mass regime. The exact contribution and time scale of the different process involved are however still to be constrained. In this talk, I will present our study of the evolution of satellite galaxies in clusters, in the Illustris and TNG simulation suites. I will focus on the evolution of both the dark matter and the baryonic components of these galaxies, and examine how different sub-populations of cluster member galaxies are affected by the cluster-specific physical mechanisms. In particular, this allows to quantify the time scale of galaxy quenching in cluster in these simulations, and to compare with other theoretical or observational studies.

KEYWORDS Galaxy evolution, Clusters, Cosmology

IAUS 373

#1723

The Impact of the Group Environment on the Molecular Gas and Star Formation Activity

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At least half of the local galaxies reside in galaxy groups, which indicates that the group is the common environment where galaxies evolve. In addition, a substantial fraction of cluster galaxies is already quenched in the group environment before they enter the galaxy cluster, which is known as “pre-processing”. Therefore, it is important to probe how significantly galaxies are affected by group environmental processes, in order to obtain a better understanding of galaxy evolution. Thus, we carried out a new CO imaging survey for 31 group galaxies in the IC 1459 and NGC 4636 groups, using the Atacama Compact Array (ACA), to study the effect of the group environment on the molecular gas and star formation activity. With our resolved CO data, combined with high-resolution HI images from the Australian Square Kilometer Array Pathfinder (ASKAP) and Very Large Array (VLA), we find asymmetric CO and/or HI distributions in our group sample. In addition, group members have relatively low molecular gas fraction and low star formation rate, compared to isolated galaxies. These results suggest that the group environment can change the properties of cold gas components and star formation, and thus can play a key role in galaxy evolution.

KEYWORDS Molecular gas, Interstellar atomic gas, Galaxies, Galaxy groups, Galaxy evolution

IAUS 373
#1677

The curious case of NGC 5068 and its neutral hydrogen fingers

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How galaxies replenish their gas supply in order to sustain star formation, is a research topic of many of the new and upcoming neutral atomic hydrogen (HI) surveys on the SKA precursor instruments. This replenishment, or accretion, of gas in the form of HI is likely to occur at column densities one or two orders of magnitude below previous observational limits and it has, so far, not been unambiguously detected.

I present recent deep HI observations of NGC 5068, an isolated nearby star-forming galaxy observed by MeerKAT as part of the MHONGOOSE survey. This survey is the deepest HI survey of nearby galaxies until the advent of the SKA and is reaching column densities of NHI (3σ) ~2x1018 cm-2 at 30′′ resolution.

The combination of the resolution and sensitivity of the MeerKAT HI data have revealed "fingers" of low column density gas extending out from the main HI disk of the galaxy. While the origin of these fingers remains a mystery for now, the dynamics of the main galaxy disk and the outer disk in which the fingers are located, as well as the morphology of the fingers, does not seem to suggest a previous merger event.

KEYWORDS galaxies, ISM, gas, star formation

IAUS 373

#1665

The statistical and physical properties of IR-bright Dust-Obscured Galaxies and SED modelling using CIGALE

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The aim of this work is to characterize the physical and statistical properties of a sample of infrared-bright dust-obscured galaxies (DOGs) by fitting their spectral energy distributions (SEDs). We examined 28 DOGs at redshifts $0.47 \leq z \leq 1.63$ discovered by combining images of the Subaru Hyper Suprime-Cam (HSC) survey, VISTA Kilo-degree Infrared Galaxy (VIKING) survey, and the Wide-field Infrared Survey Explorer (WISE) all-sky survey, and detected at Herschel Spectral and Photometric Imaging Receiver (SPIRE) bands. We have detected a significant active galactic nucleus (AGN) contribution to the mid-infrared luminosity for 75% of DOGs. Our DOGs contain several types of AGNs, the majority of AGN emission originates from Type 2 AGNs. The stellar masses of our DOGs are much larger than those found for other samples of DOGs selected at infrared wavelengths. We identified a correlation between the stellar mass and metallicity for 80% of our sample for rich metallicities, while there is no significant redshift evolution detected. Our DOG sample shows very high values in stellar masses, $\log(M^*/M_\odot) = 11.49 \pm 1.61$, compared with other samples of DOGs. We could say that our galaxies are "Overweight" DOGs (hereinafter ODOGs). DOGs seem to be in a transition period from the dusty starburst-heated to the AGN-dominated phases of the evolution of massive galaxies (e.g. Bussmann et al. 2011a; Riguccini et al. 2015), where the AGN feedback is in full action. The same applies to the extremely luminous and massive DOGs that form a small subclass of DOGs. Our study is promising to identify a type of DOG objects, ODOGs. ODOGs may indicate the end of the DOG phase, and then they become visible quasars.

Principal Component (PC) Analysis is applied to reduce the number of dimensions of our sample, removing the dependency on the observed variables. There are two significant PCs describing 72.7% of the total variance. The first PC strongly correlates with redshift, dust luminosity, dust mass and stellar mass, while far-ultraviolet (FUV) attenuation strongly correlates with the second PC, which is orthogonal to the first one. The partial correlation between the resulted physical parameters is tested, supporting the reliability of the correlations.

KEYWORDS Active galaxies, IR galaxies, Herschel SPIRE catalog, SED, CIGALE, Subaru Hyper Suprime-Cam

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#1664

Dense Molecular Gas in Extreme Galaxies: Gas Properties and CN/HCN Column Density Ratios

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The Atacama Large Millimeter Array (ALMA) is a next generation telescope with the ability to observe nearby galaxies with unprecedented angular resolution and sensitivity. ALMA gives us access to the densest molecular gas on detailed spatial scales, providing valuable insight into the physical and chemical processes that regulate star formation. I will present results from a multi-transition line study using both new and archival ALMA data of three lines each of CN and HCN in three unique extragalactic systems. These molecules have high critical densities, and their formation and destruction pathways depend on the astrochemical link between molecular gas properties and radiation field strengths. I make use of a non-LTE radiative transfer analysis, encapsulated by the code "pyradex", to estimate gas kinetic temperatures, H2 volume densities, and beam-averaged column densities of HCN. From analysis of the two CN (1-0) hyperfine components, I find that the CN emission is optically thin in all three systems (in contrast to the optically thick HCN), and therefore use an optically thin LTE approach to estimate the CN column densities. The range of gas temperatures is ~30-300 K in the three systems, with gas densities in the range of ~104-106 cm-3. The range of HCN column densities is 1014.5-1016 cm-2. I find higher HCN column densities in nuclear regions, where there is a higher surface brightness of HCN, and I find lower HCN column densities in non-nuclear regions. I also calculate the CN/HCN column density ratios and find a mean value of NCN/NHCN ~ 3 for the three systems, suggesting a relatively constant NCN/NHCN ratio regardless of the galaxy environment or radiation field conditions. These results suggest that determination of CN and HCN column density ratios will allow us to tease out the impact of UV and X-ray radiation on molecular gas chemistry, and whether a constant NCN/NHCN ratio may allow us to use CN as a dense gas tracer equivalent to HCN in future observations.

KEYWORDS ISM: molecules, galaxies: ISM, galaxies: nuclei, galaxies: starburst

IAUS 373

#1658

IR characteristic emission and dust properties of star-forming galaxies at 4.5 < z < 6.2

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The luminosity functions at z < 4 - 5 suggest that most galaxies have a relatively low stellar mass (logM_star = 10) and a low dust attenuation (A_FUV = 1.0). The physical properties of these objects are quite homogeneous.

We used an approach where we combined their rest-frame far-infrared and submillimeter emissions and utilized the universe and the redshift as a spectrograph to increase the amount of information in a collective way. From a subsample of 27 ALMA-detected galaxies at z > 4.5, we built an infrared spectral energy distribution composite template. It was used to fit, with CIGALE, the 105 galaxies (detections and upper limits) in the sample from the FUV to the FIR.

The derived physical parameters provide information to decipher the nature of the dust cycle and of the stellar populations in these galaxies. The derived IR composite template is consistent with the galaxies in the studied sample. A delayed star formation history with tau_main = 500 Myrs is slightly favored by the statistical analysis as compared to a delayed with a final burst or a continuous star formation history. The position of the sample in the star formation rate (SFR)- M_star diagram is consistent with previous papers. The redshift evolution of the log M_star versus A_FUV relation is in agreement with evolution in the redshift of this relation. This evolution is necessary to explain the cosmic evolution of the average dust attenuation of galaxies. Evolution is also observed in the L_dust/ L_FUV (IRX) versus UV slope beta_FUV diagram: younger galaxies have bluer beta_FUV. We modeled the shift of galaxies in the IRX versus the beta_FUV diagram with the mass-weighted age as a free parameter, and we provide an equation to make predictions.

Finally, if time allows I will show how to use broadbrand imaging of a sample of galaxies observed with the South Pole Telescope at the epoch of reionization to get an information on IR fine structure lines and help deriving their redshift and galaxy physical parameters

KEYWORDS galaxies, star-formation, dust, infrared, sub-mm

IAUS 373

#1444

Ram pressure stripping of the multiphase ISM: A detailed view from TIGRESS simulations

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Ram pressure stripping (RPS) is a process that removes the interstellar medium (ISM) quickly, playing a vital role in galaxy evolution. To investigate how the multiphase ISM gets affected by RPS, we introduce an inflowing, hot intracluster medium (ICM) into a self-consistently modeled ISM in a local patch of star-forming galactic disks using the TIGRESS framework. Our simulations reveal that the workings of RPS are not only direct acceleration of the ISM by ICM ram pressure but also mixing-driven momentum transfer involving significant phase transition and radiative cooling. The hot ICM passes through the low density channels of the porous, multiphase ISM, while shredding the cool ISM, and creating mixing layers. The ICM momentum is transferred through the mixing layers while populating the intermediate temperature gas. The mixed gas extends beyond galactic disks and forms stripped tails that cool back. The mixing-driven momentum transfer predicts that the more ICM mixes in, the faster the ISM moves, resulting in the anti-correlation of outflow velocity and gas metallicity of the stripped ISM. Star formation can be enhanced up to 50% compared to the model without the ICM due to the ISM disk compression by the ICM wind, whereas the quenching of star formation follows on the star formation enhancement within ~ 100 Myr for the strong RPS cases. In addition, we discuss the magnetic field properties under the ICM ram pressure based on both the TIGRESS simulations and our JVLA polarization observations.

KEYWORDS Galaxy interactions, Interstellar medium, Intracluster medium, Magnetohydrodynamical simulations

IAUS 373
#1371

The cold dense interstellar medium in the Small Magellanic Cloud

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The dense and cold interstellar medium (ISM) is fundamental to the process of star formation and its role on galaxy evolution. Stars are form in the dense cores of molecular clouds, which are mainly composed of molecular hydrogen H2, invisible at the temperatures of the cold molecular gas as it does not emit any radiation. Therefore, the study of the cold ISM is based primarily on the emission of the Carbon Monoxide molecule, CO, which radiates at the millimeter and sub-millimeter wavelengths. A fundamental requirement therefore is that the ISM contains CO. But what happens when the abundance of C and O, are low as it was the case of the conditions in the early universe when C and O had not been formed and subsequently the CO molecule? CO observations in low metallicity systems are elusive as CO emission is weak. We will present a detailed study of cold dense interstellar medium in the nearest low metallicity (0.2Zo) galaxy, the Small Magellanic Cloud.

KEYWORDS ISM, Magellanic Clouds, molecular clouds, star formation

IAUS 373
#1349

Dark Matter Deficient Galaxies and Their Member Star Clusters Form Simultaneously during High-velocity Galaxy Collisions

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How diffuse dwarf galaxies that are deficient in dark matter—such as NGC1052-DF2 and NGC1052-DF4—formed remains a mystery. Along with their luminous member globular clusters (GCs), the so-called dark matter deficient galaxies (DMDGs) have challenged observers and theorists alike. Here we report a suite of galaxy collision simulations using the adaptive mesh refinement code ENZO with 1.25 pc resolution, which demonstrates that high-velocity galaxy collisions induce the formation of DMDGs and their star clusters (SCs) simultaneously. With a numerical resolution that is significantly better than our previous study, we resolve the dynamical structure of the produced DMDGs and the detailed formation history of their SCs, which are possible progenitors of the DMDG's member GCs. In particular, we show that a galaxy collision with a high relative velocity of ~300 km/s, invoking severe shock compression, spawns multiple massive SCs (Mstar ~ 10^6 Msun) in ~ 150 Myr after the collision. At the end of the ~800 Myr evolution in our fiducial run, the resulting DMDG of Mstar ~ 3.5×10^8 Msun hosts 10 luminous Mv ~ –8.5 mag, gravitationally bound SCs with a line-of-sight velocity dispersion 11.2 km/s. Our study suggests that DMDGs and their luminous member SCs could form simultaneously in high-velocity galaxy collisions while being in line with the key observed properties of NGC1052-DF2 and NGC1052-DF4.

KEYWORDS Galaxy formation, Cosmology, Galaxy evolution, Globular star clusters, Star clusters, Star formation, Dark matter

IAUS 373

#1294

Constraining Star Formation Timescales Using the Spatial Correlations of Star Clusters and Giant Molecular Clouds

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In the hierarchical view of star formation, giant molecular gas clouds (GMCs) undergo fragmentation to form small-scale structures made up of stars and star clusters. Here we study the connection between young star clusters and cold gas across a range of extragalactic environments by combining the high resolution (1") PHANGS-ALMA catalog of GMCs with the star cluster catalogs from PHANGS-HST. The star clusters are spatially matched with the GMCs across a sample of 11 nearby star-forming galaxies spanning a range of environments (centers, bars, spiral arms, etc.). We find that after 4-6 Myr the star clusters are no longer associated with any gas clouds. Additionally, we measure the autocorrelation of the star clusters and GMCs as well as their cross-correlation to quantify the fractal nature of hierarchical star formation. Young (<10 Myr) star clusters are more strongly autocorrelated on kiloparsec and smaller spatial scales than the >10 Myr stellar populations, indicating that the hierarchical structure dissolves over time.

KEYWORDS Galaxies, star formation, stellar clusters

IAUS 373
#971

Probing neutral gas rich regions in the early universe

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Understanding the evolution of galaxies through cosmic times is one of the key issues in observational cosmology. This evolution is intimately related to the chemical enrichment of gas both within the galaxy (also called the interstellar medium, or the ISM) and surrounding it (the circum-galactic medium, or the CGM). With the advent of modern telescopes, it is now possible to detect galaxies even at high redshift (up to z~10). However, these galaxies are, by construction, the most luminous at their epoch implying a bias in the observed population of galaxies. A complementary method to probe galaxies independently of their luminosity is to detect them through the absorption induced by the associated gas along the line of sight to bright background sources. Among absorption systems, it has long been considered that damped Lyman-alpha systems (DLAs), characterized by a high column density of neutral hydrogen, corresponded to the ISM of their associated galaxies at high redshift. However, recent studies have shown that DLAs rather statistically probe the outskirts of galaxies. In our work, we focus on a subset of extreme DLAs containing the highest column density in neutral hydrogen, called the extremely strong DLAs (or ESDLAs, log(N(\HI) [atoms cm-2]) >= 21.7). High-resolution optical QSO spectra were used to obtain the HI and H2 column density, gas-phase metallicity, depletion, dust content of ESDLAs, and their spatial distance to emission regions if emission was detected within the slit of the spectrograph. ESDLAs provide a unique window to study the gas within high-redshift galaxies that have little or no active star formation. In my talk, I will discuss the properties of ESDLAs and discuss how they are very important probes of the HI-H2 transition occurring in metal-poor regions. I will also discuss how future ESDLA studies will be useful in studying metal-poor, HI-rich, ISM environments of high-redshift galaxies that are missed by most emission line surveys.

KEYWORDS DLA, quasars: absorption lines, high-redshift – galaxies: ISM, observations – astrochemistry, Lyman-Werner bands, High redshift diffuse molecular gas

IAUS 373
#941

ALMA observations of hot cores confining hyper-compact H II regions

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Recent observational evidence gathers in favor of accretion as the preferred high-mass star formation mechanism, in spite of the long-standing theoretical problems such as the radiation and thermal pressure, and the production of ionizing radiation (Larson & Starrfield, 1971; Wolfire & Cassinelli, 1987). Toward more massive young stars the situation is less clear: outflows seem to be less collimated and the circumstellar disk-like structures are better described as massive (and sometimes transient) toroids instead of disks. It is not clear right now what is, or whether there is at all, a stellar mass limit above which disk accretion is inadequate to explain the growth of a high-mass star. The currently accepted evolutionary path of high-mass stars begins inside dense and massive molecular cores, where high-mass young stellar objects (HMYSOs) accrete at rates of 10^−5 to 10^−3 M_sun yr^−1 (Tan et al., 2014). For O-type stars, we expect a fraction of 50% or more of the final stellar mass to be accreted after the K-H contraction and the onset of ionizing radiation (Hosokawa & Omukai, 2009; Zhang et al., 2014). In accordance, hyper-compact (HC) HII regions are usually associated with very high column densities (N_H2 > 10^23 cm^−2) and a high incidence (> 70%) of infalling motions detected toward the surrounding molecular gas (Klaassen et al., 2012). Therefore, in order to understand how high-mass stars gather their material, it is pertinent to study their associated ionized regions in their earliest stages. Our main science goal is to determine whether rotating hot molecular cores are common around HC HII regions. For that, we mapped using the ALMA in Band 6 the emission arising from two molecules, SO2 and CH3CN, toward five embedded HMYSOs associated with HC HII regions. We analyze the temperature, dynamics, kinematics of rotating hot cores. A large incidence of rotating cores around HC HII regions will support the basic physical picture that considers HC HII regions as bipolar, stratified, photo-evaporating ionized regions filling the low-density axial cavities that naturally form because of angular momentum conservation within the contracting, rotating molecular cores.

KEYWORDS ISM: molecules, ISM: clouds, ISM: cores, stars: formation, stars: massive, ISM: kinematics and dynamics

IAUS 373
#697

Numerical simulations of Milky Way type Galaxies

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Fundamental galactic properties, distribution of matter and physical processes that regulate galaxy evolution are influenced by star formation. However, there is no consensus on the universality of the star formation process itself — how much of it might be dependent on the large-scale dynamics of the Galaxy, or purely controlled by the local density of the gas, remains a topic of debate. Aiming to find some answers, I will present our work on investigating the role of the large-scale dynamics of the Galaxy on star formation through numerical simulations using the AREPO moving-mesh code.

Environmental effects can only be studied if a proper description of the spiral structure of the galaxy is given. Therefore, we start by attempting to reproduce the overall structure of our own Galaxy using a sample of six different models with varying stellar and gas profiles. The structures are obtained self-consistently via the evolution of the stellar disc and bulge, which move freely with no pre-given fixed potentials.

We compare our models to observations of the Milky Way, by generating longitude-velocity (lv) plots. We use these to extract the skeletons of the main features (arms, bar), as well as the contours defining the terminal velocities of the gas. The comparison between our models and the observations is then done via minimisation of the symmetrized distance between the observed and simulated features. Combining all these results, we choose an overall best fit, as well as best outer Galaxy and central region fits. Our best model serves as our Milky Way template suitable for investigating the environmental effects of the Galactic structure on the star formation process, by including chemistry, feedback, magnetic fields, and by zooming into individual molecular clouds in different environments.

KEYWORDS stars:formation, Galaxy: Milky Way, Galaxy: structure, ISM: structure, methods: data analysis, Galaxy: kinematicsand dynamics

IAUS 373

#841

The role of the ISM in star formation efficiency in m31 galaxy

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One of the most intriguing questions in modern astrophysics is how star formation occurs in galaxies since it affects their evolution. The Andromeda Galaxy is an ideal case in point. The very close distance of the Andromeda Galaxy makes it very easy to observe. Electromagnetic radiation at radio wavelengths is an effective detector for various components of the interstellar medium. These components include atomic and molecular gas (neutral and ionized), magnetic field, and relativistic particles. We also use infrared radiation to track massive and young stars. Interstellar magnetic fields and the emission of cosmic ray electrons have an extremely significant effect on radio infrared correlations in galaxies. This is evident when considering different spatial scales in galaxies. We study the relationship between dust and gas and study star formation. We study the formation of stars and calculate the rate of star formation. Interstellar magnetic fields and the emission of cosmic ray electrons have an influential effect on radio infrared correlations in galaxies. This is evident when considering different spatial scales in galaxies. We study the relationship between dust and gas and investigate star formation.

KEYWORDS Interstellar medium, Andromeda galaxy, star formation efficiency, star formation rate

The Average Dust Attenuation Curve at z~1.3 based on HST grism surveys

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Obtaining an accurate census of galaxy properties through cosmic time is crucial to our understanding of galaxy evolution, however they depend critically on our ability to correct for the effects of dust attenuation. Dust attenuation curves derived at z=0 and z~2 show significant differences in their shape and normalization, but the cause(s) behind an evolution remain unclear. We present the first average dust attenuation curve at z~1.3 based on ~900 galaxies at 0.75<z<1.5 in the WISP and 3D-HST grism surveys. Using galaxies in SDSS, we first establish that the (Hα+[NII])/[OIII] line ratio and stellar mass are good proxies for the Balmer decrement in low-spectral resolution grism data when only upper-limits on Hβ are available and/or Hα is blended with [NII]. The UV slope and normalization of the z~1.3 attenuation curve lie in-between the values for z=0 and z~2 dust curves. These changes provide supporting evidence that the average dust attenuation curve does evolve with redshift. The z~1.3 curve has a mild 2175A feature (~25% strength relative to the MW extinction curve), which is comparable to studies at 0<z<3 that derive it from SED-fitting, and suggests that the average strength may not evolve significantly with redshift. The methods we develop to can be applied to future grism surveys with JWST, Euclid, and RST, which will detect millions of galaxies and significantly improve our understanding how and why dust attenuation curves evolve.

KEYWORDS

IAUS 373
#758

YZiCS: Unveiling the Quenching History of Cluster Galaxies Using Phase-space Analysis

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The galaxies in massive clusters are by and large red and dead. Massive clusters are home to abundant dark matter and hot baryon gas and thus where complex physical processes take place, making the question difficult to answer. One useful approach to tackle this issue is to constrain the quenching timescales of galaxies. This is because each quenching process works with a different quenching timescale. In this work, we take a novel approach to constrain the quenching timescale of galaxies. First, with cosmological simulation data, we investigate how the time since infall of galaxies is distributed on the phase-space diagram, a plot of distance versus velocity of galaxies. We see a clear hint that each region on the phase-space diagram can predict the times since infall of observed galaxies (Rhee et al. 2017). Secondly, we extend this idea by applying the prediction to observed cluster galaxies. We statistically connect the SFR distribution of the observed galaxies with the time since infall distribution of simulated galaxies located at the same position of the phase-space diagram. This leaves a mean behavior of SFR of galaxies as a function of their time since infall. We then measure the quenching timescales of galaxies from the relation. We confirm that cluster galaxies generally follow the delayed-then-rapid quenching pattern (Rhee et al. 2020): (1) the e-folding time for quenching is roughly 3 Gyr before infall, (2) the pace of quenching is maintained roughly for 2 Gyr during the first crossing time, and (3) quenching becomes more dramatic after the delay time (~1 Gyr as the e-folding time). We conclude that the gentle mode of quenching during the delay time mainly affects the hot and neutral gas component of galaxies, with which SFR of galaxies is not severely affected, and then strong ram pressure causes cluster galaxies to be red and dead. Therefore, a clear red sequence of cluster galaxies is the product of a special quenching pattern of SFR of galaxies.

KEYWORDS cluster, quenching, environmental effects, ram pressure

IAUS 373
#489

A detailed study of the ISM in a massive, compact star-forming galaxy at z=6: a starburst hidden in the main-sequence population

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We exploit the gravitational amplification effect to study the cold molecular gas in a galaxy within the Epoch of Reionization via direct detection of CO(2-1). This low-J emission line allows us to characterize the ISM and star formation mode of this galaxy, and to test whether or not other widely used methods to infer gas masses are still valid at z=6. Interestingly, while our target lies around the scatter of the main-sequence of star-forming galaxies, it shows properties that resemble those from local ULIRGs and other starbursts, including a compact size, a relatively high dust temperature, a low alpha_CO conversion factor, and a short depletion time. This starburst episode is likely triggered by its compactness and/or by gravitational instabilities within its rotating disk, according to our modeling of high resolution [OIII] and [NII] observations. Without further significant gas accretion, we predict that this system will finish its star formation episode at z~5.5 with a final stellar mass in the order of 10^11 M_sun, in line with high-redshift massive quiescent galaxies. Thus, this multi-wavelength study sheds light on the gas conditions of high-redshift star-forming galaxies and on the processes that regulate the star formation activity, some of the main goals of this IAU Symposium.

In addition, this work provides us the first insights into what is expected to come with future facilities such as the ngVLA and the new Band-1 ALMA detectors.

KEYWORDS Interstellar Medium, High-redshift galaxies, Star formation efficiency, Starburst galaxies, Galaxy quenching, Gas-to-dust ratio, Radio astronomy

IAUS 373
#444

Formation of the Stellar System and the Central Gravitation-Potential Vessel of Galaxies

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The stellar systems of the present-day normal galaxies reside in the central part of the parent halos under dynamical influences of baryonic matter (stars, dust, gas, BH) and dark matter, in the central gravitation-potential vessel (CGPV), which was deepened by the dissipative contraction of baryonic matter.

The resolved field spectroscopic data of more than 200 CALIFA galaxies were used to derive the Circular Rotation Velocity Curve (Vc(R)), proxies of the dynamical mass within CGPV (Mdyn), mass of the stellar system (M*), and other dynamical/population parameters such as the specific angular-momentum (λ), the star-formation-rate (SFR), the age(τ), the heavy-element index (Z) for individual galaxies (Kalinova et al. 2017, Kalinova et al.2021).

We find an empirical relation between the dynamical mass and the mass of the parent halo (Moster, Naab, White 2013), log Mdyn = A log Mhalo + C (A~0.68, C~3.1 in solar-mass unit), which is mono-modal in contrast to the other relations typically bimodal, a low-mass branch for young disk-type galaxies and a high-mass branch for aged ellipsoid-type galaxies with the mode-transition at log M*~10.7(log Mdyn ~11.0, log Mhalo~12.5), suggesting that Mdyn might be one of important parameters to inter-relate the galaxy and the parent halo.

Our mass-dependence studies of other parameters indicate that initial baryon in-fall in massive halos produced the central ellipsoidal stellar system whose dynamics/activity hindered succeeding in-fall of angular-momentum-rich baryonic matter, while in low-mass halos not enough low-angular-momentum baryon was available to form the central ellipsoidal stellar system. These processes inevitably depend on the varying dynamical characteristics, in particular on the angular-momentum spectra, of the infalling baryonic matter of the parent halos, influenced by the merging/accretion prehistory.

KEYWORDS galaxy, stellar system, dynamical mass, halo mass

IAUS 373
#307

Measurement of star formation rate densities across the cosmic time

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We present the star formation properties of ~2000 sources detected in the Spitzer and the Herschel 70 micron and 160 micron observations. Analyzing the star formation rates (SFRs) of these galaxies provides the distribution of SFRs across the redshift range, $0 < z < 6$. We also investigate the star formation rate densities (SFRDs) based on the present analysis of SFRs with FIR luminosity and comoving volume calculated from the selected cosmic parameters.

KEYWORDS Star Formation Rate, Star Formation Rate Densities, Comoving Volume, Cosmic Parameters

IAUS 373

#296

Star Formation Histories of Dwarf Spheroidal and Dwarf Elliptical Galaxies in the Local Universe

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We present the star formation histories (SFHs) of early-type dwarf galaxies, dSphs and dEs, in the local universe(z<0.01) using a population synthesis code STARLIGHT(Cid Fernandes et al. 2005). The SFHs of early-type dwarf galaxies are characterized by pre-enrichment, metal-poor old stellar populations, early quenching of star formation, absence of moderately old stars that have ages of a few Gyr. There are some differences in the SFHs of dSphs and dEs. In particular, dSph galaxies formed old and metal-poor stars more than dE galaxies. The effects of reionization and feedback from supernova explosions are thought to be strong enough to remove the gas left, which prevent moderately old stellar populations in dSph galaxies. In contrast, the ejected gas are not completely removed from dE galaxies and fall back to ignite burst of second star formation at a few Gyr after the first period of violent burst of star formation.

KEYWORDS galaxies, dwarfs, SFHs, dEs, dSphs

e-Talks

IAUS 373

#3359

Bar-Driven Star and Star Cluster Formation and Gas Fueling to Galactic Center

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We performed high resolution hydrodynamical simulations in MilkyWay-like potential with a bar. Here, wide temperature range of radiative cooling, star formations from low temperature and high density gas, and supernova feedback are taken into account. We have found that the bar potential produces a high-density gas ring within 1 kpc from the galactic center. Gas is continuously provided for the ring via the x-1 orbit. Such high density gas within the galactic central region might correspond to the central molecular zone observed in MilkyWay. In the ring, active star and star cluster formations take place. In the ring, interactions and collisions between clouds also take place, which removes angular momentum of the clouds efficiently. As a result, gas clouds fall into the galactic center. This process supplies gas to the galactic center. Such gas supply occurs episodically rather than continuously.

KEYWORDS galaxies: evolution, galaxies: active, galaxies: star formations, galaxies: nuclei, galaxies: supermassive black holes

IAUS 373
#3285

A multi-wavelength study of the gas and star forming properties of ring galaxies

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Ring galaxies are a class of peculiar galaxies possessing distinct ring-like structures, usually composed of young stars and gas. Various scenarios have been proposed in the literature describing their formation including, rings as resonance structures driven by galactic bars; driven by galaxy-galaxy drop-through collisions and via accretion of fresh gas from the IGM. While the optical properties of ring galaxies have been studied extensively, a comprehensive high-resolution study concerning the distribution of gas and stars, as well as the kinematics for a large sample is currently non-existent. In this talk I present first results from the new HI Ring Galaxies Survey (HIRINGS) consisting of a sample of 29 ring galaxies for which high-resolution HI observations have been obtained using the Australia Telescope Compact Array (ATCA) and complemented with multi-wavelength data to study their gas, star formation and kinematic properties. I discuss the different scenarios leading to the formation and sustenance of the ring structures, such as the influence of angular momentum, bar and disk instabilities, disk midplane pressure and how these mechanisms consequently regulate the gas and star formation in the ring. Furthermore, I also discuss the gas kinematics of the ring galaxy sample to infer clues about the influence of external/environmental processes on their evolution. Such detailed studies of these peculiar galaxies are paramount to our understanding of their place in galaxy evolution and in explaining the transition of disk galaxies into the "green valley" before quenching. The HIRINGS survey will serve as a crucial step towards enriching our knowledge of ring galaxies in light of upcoming large HI surveys such as WALLABY, likely to detect many hundreds of ring galaxies.

KEYWORDS Ring Galaxies, Galaxy Evolution, Neutral Hydrogen, Galaxy kinematics, Star formation

IAUS 373
#3095

Measuring stellar feedback in galaxy disks

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We have analysed the spectra using MUSE observations of 500 pc square wide regions in 102 galaxy disks. We have extracted Star Formation Histories (SFHs) fitting stellar populations using SINOPSIS code. We analysed the recent changes in the SFHs to characterize the stellar feedback as a funtion of SFR changes. The stellar feedback was quantified using the so called "star formation self-regulator model". Thus, we were able to estimate the mass loading factors as a function of stellar mass surface density. We find good agreement with hydrodynamical simulations including SN explosions. We integrate the local mass loading factors as a function of stellar mass surface density relation using the stellar mass surface density profiles from the Spitzer Survey of Stellar Structure in Galaxies (S4G) to derive global mass-loading factors, as a function of stellar mass. The relation found is in very good agreement with hydrodynamical cosmological zoom-in galaxy simulations. We will show preliminary results combining this analysis involving SFHs with quemical enrinchement of the resolved regions of galaxies.

KEYWORDS stellar feedback, galaxy evolution, star formation

IAUS 373
#2929

Fueling and quenching star formation: from the filaments to the cluster cores

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I shall present some recent results on the transformation of galaxy properties along the filamentary structures (up to 8 cluster virial radii) and infalling groups around a set of galaxy clusters at redshift around 0.5, as well around the iconic cluster Virgo in the Local Universe.

Thanks to unprecedented large sample sizes, galaxy morphologies, star formation rates, stellar populations, atomic and molecular gas contents have been analysed in detail. They shed light on the coeval evolution of galaxies and cosmic structures. Comparing with galaxies in isolation and in the cluster cores, I will show that the physical processes that lead to star formation quenching and morphological transformation are already at play in filaments. They are primarily linked to the local galaxy density, while the distance to the filament spline is a secondary parameter. I will also highlight that, thanks to the high sensitivity of ALMA, we could reveal a new population of galaxies at z ~0.5, of gas fraction lower than classically known, while they are still forming stars at a normal rate. This will lead to a discussion of the survey selection functions.

KEYWORDS

IAUS 373
#2920

Understanding the role of compact star formation in galaxy evolution

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Massive elliptical galaxies in the local universe appear to have their high-redshift analogs in the form of extremely compact quiescent galaxies. Therefore, it seems that compact star formation appears to play a pivotal role in the evolutionary pathways of massive galaxies across cosmic history. However, it remains to be understood what this role is in the broader picture set by the main sequence and the scaling relations in galaxy evolution. The GOODS-ALMA survey is a 1.1mm ALMA survey aimed at understanding this question. The latest results reveal that compact star formation appears to be the norm in massive star-forming galaxies, and sizes as extended as typical star-forming stellar disks are rare. A population of galaxies with modest star formation rates, but which exhibit extremely compact star formation with starburst-like depletion timescales unveils. Compact star formation appears as a physical driver of depletion timescales, gas fractions, and dust temperatures. The new findings suggest that the star formation rate is sustained in very massive SFGs, even when their gas fractions are low and they are presumably on the way to quiescence. Gas and star formation compression seems to be a mechanism that allows to hold their star formation rate.

KEYWORDS galaxies: evolution, galaxies: fundamental parameters, galaxies: high-redshift, galaxies: star formation, galaxies: structure, submillimeter: galaxies

IAUS 373
#2843

Low frequency radio continuum imaging and SED modeling of 11 local luminous infrared galaxies in radio and infrared domains

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We present the detailed analysis of 11 local luminous infrared galaxies (LIRGs) from ultraviolet, through far-infrared to radio (~70 MHz to ~15 GHz) bands. We derive the physical properties through spectral energy distribution (SED) modeling using the Code Investigating GALaxy Emission (CIGALE) and UltraNest codes. The radio SEDs include our new observations at 325 and 610 MHz from the GMRT, and the measurements from public archives. Our main results are (1) radio SEDs show turnovers and bends, (2) the synchrotron spectral index of the fitted radio spectra range between −0.5 and −1.9, and (3) the infrared luminosity, dust mass, dust temperature, stellar mass, star-formation rates (SFRs) and AGN fraction obtained from CIGALE falls in the range exhibited by galaxies of the same class. The ratio of 60μm infrared and 1.4 GHz radio luminosity, the 1.4 GHz thermal fraction, and emission measure range between 2.1 and 2.9, 0.1% and 10%, 0.01 and 269.5×10 6 cm −6 pc, respectively. We conclude that the turnovers seen in the radio SEDs are due to free-free absorption; this is supported by the low AGN fraction derived from the CIGALE analysis. The decomposed 1.4 GHz thermal and nonthermal radio luminosities allowed us to compute the SFRs using scaling relations. Higher infrared SFRs are noted for merger classes than nuclear galaxies with similar nonthermal fractions, indicating a better calorimetric behavior. Furthermore, a positive correlation is noted between infrared SFR obtained 10 Myr ago (as compared to 100 Myr ago) and 1.4 GHz radio (total and nonthermal) SFRs because similar synchrotron lifetimes are expected for typical magnetic field strengths (≈50μG).

KEYWORDS radio continuum, galaxies, infrared, starformation, photometry, ISM, LIRGs

I Zw 81 - Massive S0 galaxy in the Bootes Void

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A clear scarcity of bright (massive) galaxies is detected in low-density environment of the Universe. Through this study, we attempt to understand the underlying properties of a massive galaxy (log(M*) ~ 11 $M_{\odot}$) - I Zw 81, situated inside the Bootes void . We perform detailed 2D structural analysis of the galaxy using GALFIT on CFHT g - and r - band images to find that the galaxy comprises a disky pseudo-bulge, a strong bar, a ring, an inner disk followed by a low surface brightness outer disk. I Zw 81 is disk - dominated with lenticular morphology. Both the disks combinedly contain 70% of the total light of the galaxy.

The individual colors of each component show that the bar is the bluest component in the galaxy followed by the pseudo-bulge and inner disk. The outer-disk turns out to be the reddest structural component of the galaxy. Hence, we infer that the galaxy show signs of outside-in quenching. On a sSFR vs M* plane, the galaxy is classified as star-forming despite consisting of a dominant fraction of evolved (old) population. Additionally, the AstroSat/ Ultraviolet Imaging Telescope (UVIT) observation and Hα line emission from SDSS fibre spectrum, we establish that the central region inside the galaxy covering the entire bar region is in early starburst phase.

We propose that the galaxy is formed secularly devoid of any major mergers. The centrally concentrated star formation is due to the strong bar at the galactic center. The apparent outside-in quenching mechanism is self induced as the bar causes gas inflow to the galactic center which induces the central star formation.

KEYWORDS galaxies: star formation, galaxies: elliptical and lenticular, galaxies: evolution, galaxies: formation, galaxies: disc, voids, ultraviolet: galaxies

IAUS 373

#2800

Galaxy Zoo: Clump Scout: Characterizing the local population of giant clumps using citizen science and machine learning

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At the peak of cosmic star formation (z~2), a very high fraction (~60%) of star-forming galaxies contained giant, star-forming clumps with physical scales of up to a kiloparsec. These giant clumps are rare in local galaxies, and the physical processes governing their formation and behavior remain unclear. To assemble a statistically representative population of clumps in the local universe, we launched the citizen science project Galaxy Zoo: Clump Scout. This project, hosted on the Zooniverse platform, recruited nearly 14,000 volunteers to visually identify clumps in approximately 60,000 local galaxies ($z < 0.1$) selected from the Sloan Digital Sky Survey. The Clump Scout catalog is the largest local-universe clump catalog to date, comprising more than 10,000 clumps. We then used these labels to train a deep-learning-based object-detection framework, which identified more than 45,000 potential clumps and greatly improved the clump sample's completeness. With our volunteer-identified catalog of clumps we find that only 3% of local star-forming galaxies host massive clumps, compared with more than 50% at z~2 using similar selection criteria. The sharp drop in galaxy clumpiness parallels the reduction in turbulent gas kinematics in disks over this time, which provides indirect evidence that high-redshift clumps primarily form in-situ due to violent disk instability. We additionally present analyses on the prevalence and color of clumps as a function of large-scale galaxy environment. By statistically characterizing the local-universe distribution of star-forming clumps, we are able to shed light on the way these clumps form, evolve, and impact their hosts over cosmic time.

KEYWORDS Starburst galaxies, Galaxies, Galaxy evolution, Galaxy formation, Galaxy structure, Cosmological evolution

Near-infrared-dark lensed faint ALMA sources uncovered by the ALMA lensing cluster survey (ALCS)

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The ALMA lensing cluster survey (ALCS) is an ALMA cycle-6 large program dedicated to surveying intrinsically faint continuum sources and line emitters with the assistance of gravitational lensing. All the 33 cluster fields were selected from HST/Spitzer treasury programs including CLASH, Hubble Frontier Fields, and RELICS, which also have Herschel and Chandra coverages. The total sky area surveyed reaches ~134 arcmin2 down to a depth of 0.07 mJy beam-1 (1σ) at 1.2 mm, yielding 141 secure continuum detections. In this presentation, I will describe how these ALCS sources are used to examine the origin of the extragalactic infrared background light (EBL) and characterize the physical properties of dust-enshrouded star-forming and active galaxies across cosmic time, which are considered to be responsible for the EBL. Specifically, I will focus on the nature of ALCS 1.2 mm continuum sources without any counterpart in the deep near-infrared bands including HST/F160W (H-dropout or near-infrared-dark ALCS sources). I will also present the status of spectroscopy follow-up observations of these H-dropouts using ALMA.

KEYWORDS galaxies, ALMA, dust

IAUS 373
#2744

Comparing the Inner and Outer Star-forming Complexes in the Nearby Spiral Galaxies

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We present a far-UV (FUV) study of the star-forming complexes (SFCs) in three nearby galaxies using the Ultraviolet Imaging Telescope. The galaxies are close to face-on and show significant outer disk star formation. Two of them are isolated (NGC 628 and NGC 6946), and one is interacting with distant companions (NGC 5457). We compared the properties of the SFCs inside and outside the optical radius. We estimated the sizes, star formation rates (SFR), metallicities, and Toomre Q parameter of the SFCs. Furthermore, we find that outer disk star forming complexes are metal-poor compared to the inner disk SFCs. The FUV emission is well correlated with the neutral hydrogen gas (H I) distribution and detected within and near several H I hole. Our estimation of the Toomre parameter in the outer disks of the two isolated galaxies suggests that their outer disks are stable ($Q > 1$). However, their FUV images indicate that there is ongoing star formation in these regions. This suggests that there may be some non-luminous mass or dark matter in their outer disks, which increases the disk surface density and supports the formation of local gravitational instabilities. In the interacting galaxy, NGC 5457, the baryonic surface density is sufficient ($Q < 1$) to trigger local disk instabilities in the outer disk. We will also discuss the discovery of a nearby large, diffuse galaxy, UVIT J2022. UVIT J2022 is very faint in near infrared however our FUV and Halpha maps, which are the tracers of recent and massive star formation, helped in discovering this galaxy.

KEYWORDS

IAUS 373
#2711

Modelling the SED of star-forming galaxies at z~1.6: Star formation rates and Stellar masses

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By fitting the ultra-violet to radio (including the major recombination lines) spectral energy distribution of a sample of z~1.6 star-forming galaxies in the COSMOS field with a self-consistent radiative transfer code GRASIL which includes a state-of-the-art treatment of dust extinction and reprocessing, we obtain robust estimates of the star formation rates and stellar masses of these galaxies as well as investigate their relationship.

From our best-fit models, we provide a set of star formation rate calibrations at wavelengths ranging from 3um to 1000um (including JWST MIRI instrument bands) (MIRI)). We complement these with similar calibrations at radio wavelengths which do not suffer dust attenuation as well as compare all calibrations obtained with those in the literature.

KEYWORDS galaxies

IAUS 373

#2660

7-Dimensional Sky Survey for Galaxy Evolution

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In this talk, we introduce the 7-Dimensional Sky Survey (7DS) which is a wide-field spectral imaging survey and its scientific potential for galaxy evolution study. 7DS will map 20,000 deg2 of the southern sky to a point source limiting magnitude of 20 AB mag at 5-sigma and provide a low-resolution optical spectrum (0.4 to 0.9 micron) to each pixel at a spectral resolution of R ~ 20 – 40, and a spatial resolution of 0.5". It will also perform a two weeks cadence spectral monitoring of every object in the sky area of 2,000 deg2. When all the epoch data are stacked, the stacked images can reach a point source limiting magnitude of 22.5 AB mag. With the IFU-like spectral imaging data of all galaxies within the survey area and depth, 7DS will obtain spatially resolved spectra of 50 million galaxies so that we will be able to trace the stellar population at different parts of galaxies. 7DS will also provide the data with which we can determine redshifts of many more galaxies to an accuracy of 0.3% so that we can trace large scale structures out to z ~ 1, and use the information for studying environment-dependent galaxy evolution and cosmology, as well as input galaxy catalog for multi-messenger astronomy. We will conduct 7DS with a multiple-telescope system named 7-dimensional telescope with a scheduled start date of late 2022. We expect a great synergy with a similar spectral mapping survey, SPHEREx, in such a way that we provide optical spectral mapping data while SPHEREx provides NIR data.

KEYWORDS Galaxy Survey, Galaxy Evolution, Large Scale Structure, Multi-Messenger Astronomy, Spatially Resolved Stellar Population, Galaxy Cluster

IAUS 373
#2644

Field variance forecasts of high redshift AGNs with a semi-analytic model with the Uchuu simulation

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Measurements of the luminosity function of active galactic nuclei (AGN) at high redshift (z>6) are expected to suffer from field-to-field variance, including the cosmic variance and Poisson variance.
Even for future surveys with new telescopes, such as JWST, Euclid, and LSST, the derived luminosity function can also be affected by field variance.
We use the Uchuu simulation, a state-of-the-art cosmological N-body simulation with volume 25.7 Gpc^3 and sufficient mass resolution, combined with a semi-analytic galaxy and AGN formation model, the New Numerical Galaxy Catalog (ν^2GC), to investigate the field-to-field variance of the luminosity function of AGNs.
With this Uchuu-ν2GC model, we quantify the cosmic variance, σcv, as a function of survey area, AGN luminosity, and redshift.
The cosmic variance decreases with increasing survey area and decreasing redshift.
We find that at z~6-7, σcv hardly depends on the AGN luminosity, in particular for small survey areas (0.01 and 0.1 deg^2).
This is because the typical dark matter halo mass in which AGNs reside does not monotonically increase with increasing luminosity.
Due to the rarity of AGNs, the Poisson variance dominates the total field-to-field variance, in particular, for bright AGNs.
We also examine the effects of parameters related to galaxy formation physics on the field variance.
Furthermore, we provide predictions of the variance of AGN luminosity functions in the observer-frame JWST, Euclid, and LSST bands.
We find that while the Euclid-deep survey can constrain the faint end (M_{1450}> -23), the Euclid-wide survey can determine the bright end (M_{1450}< -23).

KEYWORDS Galaxy formation, Galaxy evolution, Supermassive Black holes, Quasars, Large-scale structure of Universe

IAUS 373

#2632

The edges of star-forming galaxies

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Star-forming galaxies form new stars across their entire structure. However, after reaching a certain radius in the outskirts, their star formation drops dramatically. The radial location of where such an abrupt drop in star formation occurs marks the edge of the stellar component in star-forming galaxies. In this contribution, we will present our analysis of the edges of almost 1000 nearby star-forming galaxies using ultra-deep optical imaging. We will present how the radial location of the edges of galaxies depends on their morphology and global stellar mass. In fact, we will show that the location of the edges of galaxies is strongly connected with their global stellar mass, producing one of the tightest scaling relationships (<0.1 dex) known for galaxies over nearly four orders of magnitude in stellar mass. We will discuss the implication of our findings in the context of galaxy formation and evolution.

KEYWORDS galaxies: fundamental parameters, galaxies: formation, methods: data analysis

IAUS 373
#2569

Tug of War, or Cohabitation? : Star Formation and AGN Activities within Type 1 AGN Host Galaxies

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The interplay between star formation (SF) activity and active galactic nuclei (AGN) governs the co-evolution of supermassive black holes (SMBHs) and their host galaxies. AGN feedback has been hailed as the de facto process to suppress, or even shut down SF within the framework of hierarchical galaxy merger based on the current ΛCDM paradigm. However, it is unclear what physical processes regulate the growth of SMBHs and how SMBHs and their evolution are interconnected with their host galaxies when SMBHs and host galaxies are of hugely different physical scales. In fact, there has been no observational evidence to show that AGN feedback works, but rather some evidence to speculate that the more powerful AGNs reside in the more actively star-forming host galaxies.

While it is difficult to measure the amount of SF from AGN host galaxies, polycyclic aromatic hydrocarbon (PAH) emission features emerged as good proxies for this purpose. Although having several caveats as SFR indicators, such as metallicity dependency, and non-SF contribution from evolved stellar populations, or AGNs, PAH emissions have been utilized to investigate SF activity of AGN host galaxies with varying results.

Utilizing the slitless spectroscopic apability of the AKARI Infrared Camera, we obtained the spectra in the wavelength range of 2–5 μm from extended regions of 79 type 1 AGN host galaxies to detect and measure the 3.3 μm (PAH) emission feature as star formation rate proxy. Based on 18 sample galaxies, we found that the luminosity of the 3.3 μm PAH emission feature is strongly correlated with AGN luminosity, except for ultra-luminous infrared galaxies (ULIRGs). Therefore, we suggest that host galaxies with stronger AGN activities have stronger star formation activities.

However, it is still unclear why ULIRGs deviate from the correlation, not to mention why the detection rate of the 3.3 μm emission feature is so low. High spatial resolution imaging not only for the circumnuclear region of AGN host galaxies, but also for entire galaxies should help the cause. We present the prospective studies to diagnose SF regulation for AGN host galaxies with various space telescope facilities, such as JWST, and SPHEREx.

KEYWORDS galaxies: star formation, galaxies: ISM, galaxies: Seyfert, infrared: galaxies

IAUS 373
#2474

Classification of Local Analogs to High-z Galaxies Through Star Formation Histories

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Star-forming dwarf galaxies have properties similar to those expected in high-redshift galaxies. Hence, these local galaxies may provide insights into the evolution of the first galaxies, and the physical processes at work. We present a sample of eleven potential local analogs to high-z (LAHz) galaxies. The sample consists of blue compact dwarf galaxies, selected to have spectral energy distributions that fit galaxies at $1.5<z<4$. We use SOFIA-HAWC+ observations combined with optical and near-infrared data to characterize the dust properties, star formation rate (SFR) and star formation histories (SFH) of the sample of LAHz. We employ Bayesian analysis to characterize the dust using two-component black-body models. In adition, we use the LIGHTNING package to fit the spectral energy distribution of the LAHz galaxies over the FUV-FIR wavelength range, and derive the SFH in five time-steps up to a look-back time of 13.3 Gyr. Of the eleven LAHz candidates, six galaxies have SFH consistent with no star formation activity at look-back times beyond 1 Gyr. The remaining galaxies show residual levels of star formation at ages ≥1 Gyr, making them less suitable as local analogs. These six young galaxies stand out in our sample by having the lowest gas-phase metallicities. They are characterized by warmer dust, having the highest specific SFR, and the highest gas mass fractions. The young age of these six galaxies suggests that merging is less important as a driver of the star formation activity. The six LAHz candidates are promising candidates for studies of the gas dynamics role in driving star formation.

KEYWORDS blue compact dwarf, galaxies, star-forming, analogs, high-z, Dust, infrared

IAUS 373

#2457

A giant HI-galaxy disk of extreme low column density

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During the early inspection of the MeerKAT Galactic Plane Legacy Survey, we identified very weak extended low HI-column density emission that displays the typical signature of an open-faced, possibly barred spiral galaxy. The approximate disk size of 230 kpc categorizes this galaxy as a giant of the likes of Merlin 1. But not its HI-mass. The latter is quite low and locates this galaxy nearly two orders of magnitudes off the well-constrained narrow mass-diameter relation. Moreover, most of the disk's gas will be too low column-density to allow for star-formation. This raises the question as to how such an extended HI-disk could have formed without a stellar disk to support it - or is it a transitory stage? We will present the newest results from deeper and better resolved (both spatially and in frequency) MeerKAT observations that should tell us more this crouching giant.

KEYWORDS HI-surveys, extragalactic

IAUS 373
#2442

Star formation in strongly and weakly barred galaxies

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How does a bar affect star formation and quenching? We investigate the effect of strong and weak bars in star forming galaxies in the context of galaxy quenching and galaxy evolution. The strong and weak bars in this study were identified using Galaxy Zoo DECaLS (GZD), the newest version of Galaxy Zoo, which uses imaging from the DECaLS survey. Our sample was also cross-matched against ALFALFA for gas mass measurements. In the end, we have a volume-limited sample (0.01<z<0.05, Mr<-18.96) of 1,867 galaxies with reliable volunteer classifications.

We find a weak bar fraction of 28.1% and a strong bar fraction of 15.5%,resulting in a total barred fraction of 43.6%, consistent with the literature.Interestingly, we observed that the strong bar fraction is typically higher in quiescent galaxies than in star forming galaxies, whereas the weak bar fraction is similar in both groups.

Additionally, we found that star forming galaxies with strong bars have higher fibre SFRs, lower gas masses and shorter depletion timescales, compared to unbarred star forming galaxies. The increase of SFR in the fibre is in agreement with previous theories stating that bars funnel gas to the centre, where it is used for star formation. This was not found for star forming galaxies with a weak bar. This shows that strong bars facilitate the quenching process and suggests that bar morphology plays an important role in regulating central star formation and the quenching process.

We have also found that the differences between strong and weak bars that we observed, disappear when we control for bar length. We conclude that strong and weak bars are not fundamentally different phenomena, but instead we pro-pose that there is a continuum of bar types, which varies from 'weakest' to 'strongest'. Our results suggest that only the stronger bars are able to significantly affect their host, especially in terms of central SFR.

KEYWORDS Bars, Quenching, Central star formation

IAUS 373
#2399

Star formation at sub-kpc scales in two strongly lensed z~1 galaxies with HST and ALMA

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We study small-scale star formation processes in the Cosmic Snake arc in MACS1206 and the arc in A521, two strongly lensed galaxies at redshifts z=1.036 and z=1.044, through the observations of the Hubble Space Telescope (HST) and the Atacama Large Millimeter/submillimeter Array (ALMA). The former help us to trace star formation rate (SFR) and stellar mass (M*), and the latter H2 molecular gas mass (Mmol) and dust mass (Mdust). Our HST and ALMA observations have similar angular resolutions of 0.15''-0.2'', which with the help of strong gravitational lensing enable us to reach spatial resolutions of 30-100pc in these two galaxies. These resolutions are close to the resolution of nearby galaxy studies. We study the radial profiles of SFR, M*, Mmol and Mdust surface densities of these high-redshift galaxies, and compare the corresponding scale lengths with those of local galaxies. We observe from the radial profiles that the star formation is more efficient in these z~1 galaxies than in nearby galaxies. The enhanced resolution allows us, moreover, to investigate for the first time the Kennicutt-Schmidt (KS) law (SFR-Mmol surface densities) at different spatial scales, from galactic scales to ~100pc scales, in galaxies at z~1. We test the KS law in cells of different sizes in the galaxies, as well as in apertures centred on individual star-forming regions and molecular clouds. We observe that the KS law is valid at z~1, although it is offset implying shorter molecular depletion time scales. In addition, we find that the KS law breaks at noticeably larger scales than in local galaxies.

KEYWORDS

IAUS 373
#2389

Effect of gas percentage and morphology of the galaxies during minor mergers on the star formation rate

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Mergers and Interactions of galaxies are major drivers of star formation. We study the effect of minor mergers on star formation using simulations. We use Gadget4 code which has both collisionless and hydrodynamical particles. Our goal is to establish a relation between gas percentage present in the galaxies and the morphology of the galaxies on the star formation in the merged galaxy. We use 1:10 minor mergers and change the gas percentage from 0-40 and run individual simulations and study the star formation in the final galaxy. We observe that the star formation increases as the gas percentage increases. We also did simulations where the secondary galaxy has gas in it and study the effect on the primary galaxy after the merger. We also study the influence of the morphology of the primary galaxy on star formation. For this we use different Bulge to Disk (B/T) ratios varying from 0.1 to 0.9 with a constant gas in the primary galaxy and run simulations. We observe that the galaxies with lower B/T ratios have more star formation than that with the higher B/T ratio. We conclude that minor mergers with higher gas percentage and lower B/T ratios will have more star formation.

KEYWORDS Gadget4, Minor Mergers, Gas fraction, Star Formation

IAUS 373
#2352

Cubelet Stacking - A New Way of Spectral Stacking for 21cm Interferometric Data

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In this talk I will introduce a new stacking technique for interferometric data - \textit{cubelet stacking}. I will talk about the limitations of the traditional method, and the validation of the new with an accurate $\rm \Omega_{HI}$ measurement with the DINGO-VLA data in GAMA 09 field. It is initially tested for 21cm spectral stacking sciences, but it should also work for other frequencies. Unlike the traditional spectral stacking technique, which stacks one-dimensional spectra extracted from data cubes, we examine a method based on image domain stacks that makes deconvolution possible. We use 3622 galaxies observed from the GAMA survey as a mock sample to test this new stacking strategy. Using the noise-free simulation we note that the stacked image and flux estimation are dramatically improved compared to traditional stacking. For a more realistic case of a stack with finite S/N, we also produced 20 different noise realizations to closely mimic the properties of the DINGO-VLA interferometric survey, and recovered the predicted average HI mass to within ~4 per cent. Overall this technique extends the range of science applications where stacking can be used and is especially useful for characterizing the emission from extended sources with interferometers.

KEYWORDS galaxies, ISM, radio lines, atoms

IAUS 373
#2160

BISTRO:
Magnetic Fields in the Serpens Main Molecular Cloud

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We study the magnetic fields in the Serpens Main molecular cloud consisting of two subclusters and six filamentary structures, as part of the B-fields in Star-forming Region Observations (BISTRO) survey that is a large program using the James Clerk Maxwell Telescope (JCMT) to study the roles of magnetic fields in molecular clouds on intermediate scales (a few thousands au or larger scales). Using the Histogram of Relative Orientation (HRO) technique, which compares polarization directions with density gradients, we find that magnetic fields are parallel to filaments in less dense regions, N(H2) < ~1022 cm-2, but perpendicular to dense filamentary structures. Furthermore, applying the HRO technique to denser core regions we identify the density regimes in which the relative magnetic field orientations change again. These transitions are understood to happen where core formation occurs (N(H2) ≈ 4.6 × 1022 cm-2) and where magnetic fields are dragged-in by infalling material (N(H2) ≈ 16 × 1022 cm-2). In addition, the magnetic field strengths in filamentary structures are estimated by the Davis-Chandrasekhar-Fermi method and compared with turbulence and gravity.

KEYWORDS magnetic field, Serpens Main, molecular cloud, JCMT, BISTRO, HRO, DCF

IAUS 373

#2210

Revealing the nature of a Lya Halo in a strongly-lensed interacting system at z~3

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Spatially extended halos of H I Lyman Alpha (Lyα) emission are now ubiquitously found around high-redshift star-forming galaxies. But our understanding of the nature and powering mechanisms of these halos is still hampered by the complex radiative transfer effects of the Lyα line and the limited angular resolution afforded by standard IFU observations. In this contribution, we present resolved Multi Unit Spectroscopic Exlorer (MUSE) observations of SGASJ1226 a strongly-lensed pair of L* galaxies at z=2.92 embedded in a bright Lyα halo. The combination of the MUSE capabilities with the extreme lensing magnification allowed us to resolve the properties of the gas down to sub-kpc scales. We find that the line width and peak velocity are correlated and vary significantly across the halo, although the line shape is consistently redshifted and asymmetric. Such a line profile is characteristic of resonant scatter of Lyα photons in galactic outflows, a picture that is further supported by the presence of blueshifted low-ionization metal lines toward the central galaxies. Detailed radiative transfer modeling of the line in 24 PSF-independent spatial bins (assuming an outflow scenario) was used to infer the intrinsic velocity field and density map of the gas. Interestingly, the outflow is slightly anisotropic as it shows higher velocities along the minor axis of the halo and perpendicular to the projected line between the central galaxies, suggesting a biconical geometry. We also identify a UV faint (M_1500 ~ -16.7) companion detected in both Lyα and continuum, whose properties are in agreement with a predicted population of satellite galaxies that contribute to the extended Lyα emission. Finally, we discuss the impact of the interaction between the central galaxies on the properties of the halo and alternative powering mechanisms such as fluoresence or gravitational cooling.

KEYWORDS Lyman Alpha Halos, Lyman Break Galaxies, Strong gravitational lensing

IAUS 373
#2209

The Extragalactic Database for Galaxy Evolution (EDGE)

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The EDGE-CALIFA survey provides spatially resolved IFU and CO spectroscopy for 126 nearby galaxies, selected from the CALIFA main sample. We have assembled the spatially resolved products of the survey into Astropy-compatible pixel tables that reduce the oversampling in the original FITS images and facilitate comparison of pixels from different images. By joining these pixel tables to lower dimensional tables that provide profiles, integrated spectra, or global properties, it is possible to investigate the dependence of local conditions on large-scale properties. In this short video talk I provide an overview of EDGE, with examples of the use of the database to conduct analysis and generate plots.

KEYWORDS Galaxy Surveys, IFU

Astronomy for All
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IAUS 373
#2168

Physical Conditions in the LMC's Quiescent Molecular Ridge

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The Molecular Ridge in the LMC extends several kiloparsecs south from 30 Doradus (30 Dor), and it contains ~30% of the molecular gas in the entire galaxy. However, the southern end of the Molecular Ridge is quiescent—it contains almost no massive star formation, which is a dramatic decrease from the very active massive star-forming regions to its north, 30 Dor and N159.

We present ALMA molecular line observations of the Ridge and analyze these with our new multi-line non-LTE fitting tool to produce maps of kinetic temperature, volume density, and column density across the region based on models from RADEX. We find that this fitting tool allows us to more directly probe the physical conditions of the gas and estimate values of kinetic temperature, volume density, and column density that are less subject to the effects of optical depth and line-of-sight projection than previous methods. The fitted volume densities show a strong correlation with the presence of YSOs, and with the total and average mass of the associated YSOs. Typical star formation diagnostics, such as mean density, dense gas fraction, and virial parameter, do not show a strong correlation with YSO properties.

We also compare the Ridge with ALMA 13CO observations of the massive-star-forming regions 30 Dor, N159, and N113, all at a resolution of 3pc. We segment the emission from each region into hierarchical structures using dendrograms and analyze the sizes, masses, and linewidths of these structures. We find that the Ridge has significantly lower kinetic energy at a given size scale and also lower surface densities than the other regions, resulting in higher virial parameters. This suggests that the Ridge is not forming massive stars as actively as the other regions because it has less dense gas and not because collapse is suppressed by excess kinetic energy.

KEYWORDS star formation, ISM, LMC, ALMA

IAUS 373
#2148

Evidence for supernova feedback sustaining gas turbulence in nearby star-forming galaxies

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The cold gas in star-forming galaxies is highly turbulent on a large range of spatial scales. However, turbulent energy is expected to be rapidly dissipated into heat through viscosity, implying that some energy source is required to explain the observed velocity dispersion of the gas. Supernova (SN) explosions are among the primary candidates. Previous studies have shown that the star formation rate (SFR) is high enough to feed turbulence through SNe in the inner regions of galactic discs, while it seems insufficient in their outskirts. Alternative mechanisms (e.g. magneto-rotational instability, gas accretion) have been proposed in order to sustain turbulence, but its primary engine has remained unknown so far.

The key novelty of my approach consists in taking into account the increased turbulence dissipation timescale associated with the flaring in outer regions of gaseous discs. By measuring the distribution and kinematics of HI and CO, I obtained the radial profiles of the kinetic energy per unit area for both the atomic gas and the molecular gas in 10 nearby galaxies, both spirals and dwarfs. I used a simple theoretical model to reproduce the observed energy with the sum of the turbulent energy from SNe inferred from the observed SFR surface density and the gas thermal energy. For both the atomic gas and the molecular gas, the observed kinetic energy is remarkably well reproduced by the model across the whole galactic disc. Remarkably, this was achieved by assuming that the SN efficiency (i.e. the fraction of the total SN energy that goes into feeding turbulence) is constant across the galactic disc. In agreement with the theoretical expectations, it was found that SNe alone can sustain gas turbulence in nearby galaxies with only a few per cent of their energy (i.e. ~1% efficiency), finally solving a long-standing conundrum in astrophysics and offering a constraint for numerical simulations.

KEYWORDS stellar feedback, gas kinematics and dynamics, ISM structure, spiral galaxies, dwarf galaxies

IAUS 373

#2138

The volumetric star formation law

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Star formation laws link the star formation rate (SFR) density and the gas density of galaxies, being crucial for both numerical and analytical models of galaxy formation and evolution. Generally, an empirical relation, the Kennicutt law, is adopted to link the SFR and gas surface densities with a break at the gas densities below a critical threshold for efficient star formation. However, the surface densities measured in galaxies are subject to projection effects due to the gas disc thickness. The intrinsic and desirable quantities to build empirical star formation laws are the volume densities, which are unfortunately not easily accessible to observations. Moreover, converting the surface densities to the volume densities is problematic, as the gas disc thickness strongly varies with the galactocentric distance and between different galaxies. Thus far, the surface densities have been largely used to build star formation laws, but it is still unclear if a more fundamental relation exist for the volume densities.

I present a method based on the hydrostatic equilibrium to accurately derive the radial profile of the gas disc thickness for galaxies with robust measurements of the gas kinematics and mass models. I applied this method to 11 spiral galaxies (including the Milky Way) and 12 HI-rich dwarf irregular galaxies in the local Universe. I converted the observed (at kpc-scales) surface densities of the total gas (HI+H2) and SFR into the corresponding volume densities. I found that all the galaxies in the sample closely follow the same quadratic power law involving the total gas and SFR volume densities. This volumetric star formation (VSF) law has a smaller scatter than the Kennicutt law and no break, suggesting that there is no density threshold (no drop in efficiency) for star formation regardless of the location within galaxies. This may imply that the current recipes implemented in numerical and analytical models of galaxy formation and evolution need revision.

KEYWORDS star formation, ISM structure, spiral galaxies, dwarf galaxies, gas kinematics and dynamics, star formation laws

IAUS 373

#2115

The NGFS census of Baryonic Structures, their Formation and Assembly in a nearby Cluster Environment

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A crucial question in astrophysics is how the baryonic structures assemble over cosmic time. This presentation will show results on this topic, specially using the low surface brightness galaxy regime and their stellar populations to get insight about a nearby galaxy Cluster, Fornax (20 Mpc).

We use the Next Generation Fornax Survey (NGFS) to complete a census of its baryonic structures in a panchromatic, deep and wide scale coverage: i) Optical filters u'g'i' and Hα with CTIO/DECam and in the NIR J,Ks filters with ESO/VIRCAM. (ii) Reaching GC masses of 10^5 $M_{\odot}$ and surface brightness of 28-29 mag/arcsec2. (iii) Covering the Fornax virial sphere (50 deg^2).

The NGFS science goes from giant to dwarf galaxies and from the bright to low surface brightness regime, besides the study of their stellar population (unresolved), mainly through their nuclear star clusters, globular clusters and ultra compact dwarf galaxies population. I will present our findings using the whole NGFS coverage in terms of the detection and analysis of the low surface brightness galaxy regime and what their stellar populations can tell us about the complex history of this cluster. In addition, a comparison between the central region of the Fornax cluster (Eigenthaler+2018, Ordenes-Briceño+2018b, Muñoz+2015) and the outer regions will be presented.

KEYWORDS Fornax Galaxy Cluster, Low surface Brightness galaxies, Nuclear star clusters, Globular clusters, Quenching processes, Galaxy evolution

IAUS 373
#2107

Quantifying the contamination from nebular emission in NIRSpec spectra of accreting pre-main sequence stars in massive star forming regions

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I will present results from simulated NIRSpec data that will be complemented by preliminary results from epoch 1 observations of pre-main sequence (PMS) stars in star forming regions (SFRs) in the Milky Way and Magellanic Clouds. These observations are part of the JWST Guaranteed Time Observing programme using NIRSpec, NIRCam and MIRI. In particular, I will focus on the determination of mass accretion rates $\dot{M}acc$ of PMS stars, using emission line luminosities.

Measuring spectra of extragalactic PMS stars will be possible for the first time thanks to JWST's angular resolution of 0.07 arcseconds at 2 micron, which is about 100 times finer than Spitzer and Herschel. A challenge with studying SFRs with NIRSpec is measuring the nebular contamination and removing it from the stellar spectra. The NIRSpec pipeline is not designed for this, as it is built around the study of distant galaxies. I will describe the approach used to assess the performance of the NIRSpec background subtraction, and show that the equivalent width of simulated stellar emission lines can be recovered to within 10%. I will also show that a spatially variable background on the angular scale covered by the MSA configuration of 3 microshutters introduces an additional uncertainty of no more than 10%. Given a typical EW of >20Å for the stellar emission lines, this uncertainty does not prevent the reliable measurement of accretion luminosities. The results from the simulated data and observations will be compared and this will provide a framework for measuring $\dot{M}acc$ of PMS stars along with the associated uncertainties.

KEYWORDS JWST, NIRSpec, Nebular emission, Massive star forming region, Disk accretion, background subtraction, Magellanic Clouds

IAUS 373

#2003

Resolving ionized and stellar bar-like flows with MUSE

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Barred galaxies are among the most common objects in the Universe and even when they are relatively easily identified in continuum images, their kinematic signatures have not been properly characterized on velocity fields. In this work we present spatially resolved studies of 14 barred galaxies observed with MUSE. We observe the presence of non-circular motions in the form of oval distortions on the stellar and ionized velocity maps induced by the presence of the stellar bar. From applying circular rotation models we observe that bars leave symmetric structures on the residual maps of the stellar velocity maps. Signatures detected due to the high-spatial resolution of the data. These residual structures can be caractezed with kinematic models that include a bar-like perturbation in the potential (bisymmetric & harmonic models). We find that the position angle of the oval distortion estimated from the bisymmetric model correlates with the photometric bar position angle (r_pearson = 0.95), which suggest that non-circular velocities are caused by the bar. However because of the low amplitudes of the s3 harmonic radial flows we can not rule out as possible source. We show that when galaxies are gas rich, bar-like flows are detected in the stellar and ionized gas.This demonstrates that gas and stars react to the bar potential. However, bar-induced velocities have larger speeds in the ionized gas than their stellar counterparts. Finally, we do not find evidence that the amplitude of the bar-flows is determined by the bar size, stellar mass or the global SFR.

KEYWORDS Kinematics, Barred galaxies, Non-circular motions

IAUS 373
#1924

The connection between assembly history, asymmetry, and star-formation

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Observational results demonstrate a relationship between star-formation and asymmetry for galaxies in the local Universe. Asymmetric galaxies are statistically more likely to be starbursts. Meanwhile, the least morphologically asymmetric galaxies are more likely to be quenched. To study the origin of asymmetry and its connection to quenching, we create synthetic HSC-SSP observations of TNG50 galaxies with dusty radiative transfer and rigorously incorporate observational effects. These survey-realistic synthetic images enable connections between galaxy observables (such as their line-of-sight morphologies) and intrinsic non-observables (stellar assembly and gas accretion histories). Using the asymmetries and morphological parameters derived from these synthetic images, we first contrast the connection between asymmetry and star-formation/quenching to observations. Then, using the known summary statistics of galaxy assembly histories (major/minor merger frequencies, lookback times, and ex-situ stellar mass fractions) we statistically examine the origins of asymmetric structure and its relationship to star-formation and quenching in galaxies. Our results provide an origin story for the relationship between asymmetry and quenching in observed galaxies.

KEYWORDS galaxies, morphology, mergers, asymmetry, star formation, quenching

IAUS 373
#1922

Density slopes of galaxies up to redshift ~ 0.5 from spatially resolved MUSE stellar dynamics

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Cosmological simulations show in-situ central star formation and gas-rich mergers at early times led to galaxies with steep total mass density profiles. At later times, gas-poor mergers gradually `puff-up' the galaxy, resulting in shallower density profiles. Simulations of galaxies through cosmic time indicate the average density slope of galaxies was as steep as -3 at redshifts of ~2, and approaches the `isothermal' slope of -2 in the local Universe. This trend found by simulations agrees with local Universe dynamical modelling results, showing on average isothermal density slopes. However, at intermediate redshifts ($0.3 < z < 1$), gravitational lensing measurements of density profiles show the opposite evolution, namely that density slopes were more shallow at greater lookback times. In this talk I will present the results of Jeans Anisotropic MGE (JAM) dynamical modelling of 90 early-type galaxies in the Hubble Space Telescope Frontier Fields sample in the redshift range $0.3 < z < 0.54$, using the same methods as local Universe studies. The dynamical models incorporate 2D MUSE stellar kinematic maps. The results of this study indicate no evolution in the density slope in the past ~ 5 Gyrs of cosmic time, supporting a dry merger mode, and in tension with gravitational lensing results. I will extend the results of the Frontier Fields study by presenting early data and results from the MAGPI survey, a MUSE large-program survey designed to study galaxies in the `middle ages' of the Universe. The MAGPI survey aims to provide a resolved, in-depth understanding of accretion, angular momentum change, and the environmental impact on galaxy evolution at $z \sim 0.3$. I will present the results of 2D resolved dynamical models using MAGPI data and compare these to the high-density envinronment Frontier Fields results. Combined with local Universe studies, we can trace the evolution of the total density slope across ~5 Gyrs of lookback time across high and low density environments using a consistent method.

KEYWORDS galaxies, dynamics, kinematics, environment

IAUS 373
#1909

Clues about Galaxy Assembly from the Number of Globular Cluster versus Black Hole Mass Correlation in Spiral Galaxies

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Until recently, only five spiral galaxies (M 31, M 81, M 104, NGC 253, and the Milky Way --MW) had been compared to the N_GC versus MBH correlation defined by massive ellipticals, and only the MW did not seem to comply with it. We have now measured N_GC versus MBH in NGC 4258, NGC 4736, and NGC 4826. All of them have a pseudobulge, like the MW, although NGC 4258 and NGC 4826 seem to also have a classical bulge.

While NGC 4258 lies on the correlation and NGC 4736 may be consistent with it, NGC 4826 is not. Neither is NGC 253, likewise a pseudobulge galaxy, that had so far been placed incorrectly on the N_GC versus MBH diagram. Hence, including the MW, there are now three spirals that deviate from this relation in the sense that their central black holes are less massive than expected from their numbers of GCs.

One possible link between bulge type, N_GC, and MBH is local density, and hence major merger events. Like the MW, NGC 4826 and NGC 253 belong to small groups, respectively, Canes I and Sculptor. NGC 4258, on the other hand, is the brightest member of another small group, Canes II; although it lies on the N_GC versus MBH correlation, it also has an exceptional system of old and metal-poor GCs that has a disky configuration, and appears to be aligned with and rotating as fast as the HI disk of the galaxy. It would be hard to explain that its GC disk could have survived too many mergers. If, on the other hand, the GC disk were accreted, it would also be hard to explain why it shares the HI disk orientation and velocity. And, although not quite reaching the HI disk velocities, the GC systems of four galaxies in the Sculptor Group, including NGC 253, also seem to be organized in rotating disks. Together with simulations and observations of clumpy star-forming disks at z ~ 2, the discovery of GC disks in the local universe supports the idea that GCs probably formed in disks, and came to populate halos through multiple mergers. It also underlines the different quality of low density, Local Group-like environments, for the formation of supermassive central black holes and their correlations with their host galaxies. Clearly, more statistics are needed, but the relation (or lack thereof) between N_GC and MBH in spirals can provide fundamental clues about galaxy assembly.

KEYWORDS galaxies:formation, galaxies:evolution, globular clusters, black hole correlations, galaxies:spiral, galaxies:kinematics and dynamics

IAUS 373
#1559

Cold neutral gas in galaxies at 0.4 < z < 1.0: First results from a large-area 21-cm HI absorption survey

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Cold neutral hydrogen gas (HI) traces the fuel supply available for star formation across cosmic time, but our knowledge of the amount and distribution of HI in galaxies beyond the local Universe remains patchy and incomplete. At radio wavelengths, the 21-cm HI absorption line provides a unique and unbiased probe of HI in distant galaxies that is unaffected by dust and requires no optical pre-selection. Crucially, the 21-cm line preferentially traces colder gas (T ~ 100K) and so directly probes the gas reservoirs responsible for star formation. We present early results from the First Large Absorption Survey in HI (FLASH), which is surveying the whole southern sky for HI 21-cm absorption in the redshift range 0.4 < z < 1.0 with the wide-field SKA precursor telescope ASKAP. We will present new detections of intervening HI absorption lines from the first 3000 square degrees of the survey and discuss the physical condition of the line-of-sight HI gas. We will also discuss the relationship between this cold HI gas and the star-formation rate and other properties of the surrounding galaxies, using information from follow-up studies with optical/IR data.

KEYWORDS galaxies: ISM, galaxies: active, galaxies: evolution, quasar: absorption lines, radio lines: galaxies

IAUS 373
#1856

Simulating star formation in NGC4303 and NGC3627: does bar origin matter?

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Simulation results, initialised from observations of nearby NGC4303 and NGC3627, are used to investigate evolutionary trends in the star formation of barred galaxies. These resolved galaxies are prime targets for studying the effects of galactic bar morphology on the star forming ISM and, with the former effectively isolated and the latter part of an interacting system, the impact of different formation mechanisms on bar-related star formation. While general star formation features appear relatively similar in each case, such as the starburst upon bar formation and the slope between surface gas density and star formation rate, some significant differences are identified and attributed to bar origin. Throughout the star forming history of the tidally driven disk, for example, the spatial dependence of star formation efficiency is found to be monotonically increasing towards larger radii with a highly inefficient region persisting along the bar, directly between the centre and each end. This is coupled with kinematic and dynamical behaviour for these newly-formed stellar populations, traced within the developing disk structure. So we ask: if bar origin also independently impacts trends of star formation and stellar motion, could these be used to actively identify evolutionary histories in observed galaxies?

KEYWORDS galaxies: bar, galaxies: interactions, stars: formation, methods: numerical, galaxies: kinematics and dynamics

IAUS 373

#1822

A gradual decline of star formation since cluster infall: new kinematic insights into environmental quenching at 0.3 < z < 1.1

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The environments where galaxies reside play a key role in shaping their star formation histories over cosmic time. We demonstrate that galaxies show a gradual decline of star formation after entering into cluster environments up to z ~ 1. Spanning a huge range in cosmic time (~5.2 Gyr, z=0.26—1.13) and adopting an advanced measure using kinematics, our study provides new constraints on the environment-dependent quenching scenarios in galaxy clusters. We constructed a large sample of 105 clusters and 1563 spectroscopically-confirmed member galaxies from the South Pole Telescope survey. Intriguingly, we find a clear signal showing a gradual increase in the mean age (through a 4000 A break index) of the galaxy's stellar populations with the time spent in the cluster environment. This environmental quenching effect is found regardless of galaxy luminosity (faint or bright) and redshift (low-z or high-z), although the exact stellar age of galaxies depends on both parameters at fixed environmental effect. In summary, galaxies experience a gradual suppression of star formation post-infall into cluster environments, due to longer exposure time to environmental effects such as ram pressure stripping and strangulation.

KEYWORDS galaxies, clusters of galaxies, star formation, galaxy formation, galaxy evolution

IAUS 373

#1836

Star-formation variability as a probe for the baryon cycle within galaxies

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We will present new results on how star formation is regulated and how this is linked to the cycling of baryons in-and-out and within galaxies. These results are based on idealized numerical simulations of Milky Way mass galaxies, in which we systemically vary the morphological setup (bulge-to-disk ratio) and stellar feedback strength (total of 80 simulations). We then study the temporal and spatial variability of the gas mass and star-formation rate (SFR) within galaxies by means of the temporal and spatial power spectrum density (PSD).

Interestingly, stronger stellar feedback leads to less bursty (more continuous) star formation, and the correlation timescale of the star-formation history (SFH) is longer. By following individual gas parcels through the disk and spiral arms, we find that stronger feedback dissolves the cold, dense star-forming gas, leading to a more homogeneous interstellar medium (ISM), and the residence time of the gas in the diffuse phase increases. The bulge strength has a similar effect: the deep gravitational potential in a bulge-dominant galaxy imposes a strong shear force that effectively rips the ISM gas clumps; this subsequently inhibits the fragmentation and reduces the star formation in the disk, leading to a more continuous star formation.

These results suggest that observations of the temporal and spatial PSD of the gas mass and SFR enable to connect between the ISM physics and the star-formation processes. This implies that even from an integrated measurement of the SFH of unresolved galaxies, we can constrain the internal workings of galaxies.

KEYWORDS Galaxy, star-formation, stellar feedback, galaxy morphology, interstellar medium

IAUS 373
#1823

Spatially resolved dust-to-gas mass ratio and metallicity relation in local galaxies from TYPHOON survey

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We present preliminary results of the relation between dust-to-gas mass ratio (DGR) and gas-phase metallicity (Zgas) of nearby galaxies on kiloparsec scales. We use optical Integral Field Spectroscopy (IFS) data from the TYPHOON/PrISM survey and combine it with publicly available UV to sub-mm and H I 21cm data. For our region-by-region analysis, we match the spatial resolution to the lowest resolution data (e.g., 37” for Hershel/SPIRE 500um). When deriving dust mass, we model dust SED using the MAGPHYS SED modelling code. Taking advantage of the large Field-of-View and range of galaxy types (dwarf to large spiral) in the TYPHOON survey, we cover a large metallicity range on the DGR-Zgas and examine the break of the relation at low metallicity regime for our sample galaxies.

KEYWORDS Galaxy evolution, Local Universe

IAUS 373
#1818

Evolution of faint submillimeter galaxies at z<4

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In this work we present a demographic analysis of the physical and morphological properties of a population of faint submillimeter galaxies (SMGs, $S_{850\mu\rm m}\sim 3~rm mJy$), selected at 450 and $850~\mu\rm m$ from the deep survey targetting the Extended Groth Strip by the SCUBA-2 Cosmology Legacy Survey. We derive the main sequence of optically selected star-forming galaxies (SFGs) in the field and explore the location of the faint SMGs. Most SMGs fall within 3σ of the main sequence and 33~per cent of these galaxies have at least 3 times the SFR of the main sequence at the corresponding stellar mass ($R_{\rm SB}(\rm SFR/SFR_{\rm MS})>3$) and could be classified as starbursts. We explore the morphological properties of SMGs and SFGs in H-band, finding that on average these SMGs have 50~per cent larger sizes than SFGs in the same mass range at $2<z<3$. This is also the redshift range where we find the largest fraction of starbursts, and hence we could be witnessing merging processes. When we select SFGs of similar stellar mass to SMGs, both populations show a similar evolution of concentration and asymmetry towards lower redshifts. These findings further support the claim that faint SMGs are mostly a population of massive dust-obscured disk-like galaxies that develop larger bulge components at later epochs, but their evolution is similar to other massive star-forming galaxies in the field.

KEYWORDS Galaxies, Star-formation, Submillimeter galaxies, morphology

IAUS 373
#1682

The Complex Star Formation History of the Halo of NGC 5128 (Cen A)

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NGC 5128 galaxy is a giant elliptical galaxy located in the Centaurus group of galaxies at 3.8 Mpc. Based on various features of this galaxy, it is always the target of many scientists to study Cen A from different aspects such as recent star formation, molecular clouds, AGN activity, and the supermassive black hole at the center of the galaxy.

We aim to study the star formation history (SFH) of two different fields of the galaxy that they are 25 kpc far from each other. The first, the northeastern field (Field 1), is located at a distance of 18.8 kpc, while the southern field (Field 2) is at 9.9 kpc. We use a photometric method that is based on identifying long period variable (LPV) stars and asymptotic giant branch (AGB) stars, as they are strong tracers of star formation and galaxy evolution due to their luminosity and variability, as well as initial mass function (IMF) of Kroupa (2000) and evolutionary models identified by Marigo et al. (2017).

These two fields present similar SFHs, although the SF rate of Field 2 is more enhanced, while they are 25 kpc apart from each other on two different sides of the galaxy. We find that the galaxy has three major star formation episodes, which are dated to be around log t(yr) ~ 8.9 (t ~ 800 Myr ago), log t(yr) ~ 9.5 (t ~ 3.2 Gyr ago), and log t(yr) ~ 9.9 (t ~ 8 Gyr ago) where t is lookback time. The highest rate of star formation is at ~ 800 Myr ago, which agrees with previous studies suggesting that the galaxy has experienced a merger around that time. Furthermore, NGC 5128 has experienced a lower star formation rate in its recent history which could have been driven by a jet-induction star formation and multiple outbursts of AGN activity in this galaxy.

KEYWORDS Stars: formation, Galaxy : evolution, Galaxy : halo, galaxies : groups: individual: NGC5128, galaxies: star formation, galaxies: jets

IAUS 373
#1686

The Isaac Newton telescope monitoring survey of local group dwarf galaxies. VI. The star formation history and dust production in Andromeda IX

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We reconstruct the star formation history (SFH) of And IX, one of the metal-poor dwarf spheroidal satellites of M 31 and closest to the host by probing asymptotic giant branch (AGB) stars.

AGBs are a handy tracers of the SFH because they are easy to detect due to their long period variability in luminosity. We identify 50 LPVs through the photometry of resolved stars in And IX using the Isaac Newton Telescope (INT) in two filters, Sloan i' and Harris V.

In this study, we selected LPVs within two half-light radii with amplitudes in the range of 0.2-2.12 mag.

We find that the peak of star formation reaches 0.00082 M_sun yr^(-1) at 6 Gyr ago. We calculate the total stellar mass by integrating the star formation rate (SFR) within two half-light radii 0.3*10^6 M_sun. By employing the spectral energy distribution (SED) fitting for observed LPVs in And IX, we evaluate mass-loss rate in the range of 10^(-7) -10^(-5) M_sun yr^(-1). Our findings suggest an outside-in galaxy formation scenario for And IX with a quenching occurring 3.8 Gyr ago with SFR in the order of 0.0002 M_sun yr^(-1) at redshift < 0.5.

Finally, we show that the total mass deposition to the interstellar medium (ISM) is 4.35*10^(-4) M_sun yr^(-1) from the C- and O-rich type of dust-enshrouded LPVs. Also, the total mass-loss enrichment ISM relative to the total stellar mass is 1.45*10^(-9) yr^(-1). Finally, we estimate a distance modulus of 24.57 mag based on the tip of the red giant branch (TRGB).

KEYWORDS Galaxy: Andromeda Galaxy, Galaxy: evolution, Dwarf galaxy, And IX

IAUS 373

#1637

Tracing the inflow history in galaxies using variability in metal yields

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Inflows of pristine gas are expected to be the main driver of sustained star formation in galaxies by providing the material needed to form the stars. Since the gas in the halo is very metal-poor an inflow will lower the metallicity of the ISM compared to its evolution in a closed box. We compare the star formation histories (SFHs) of MaNGA galaxies to their chemical enrichment histories (ChEHs) using a detailed enrichment model to predict the metal yield that the SFHs would produce and therefore the expected ChEHs. Comparing the measured and predicted ChEHs at each time we can infer the necessary inflow of pristine gas that would be required to reconcile them. We find that for the average SFHs and ChEHs of the sample a positive inflow with a maximum a few Gyr ago is obtained, reminiscent of the Madau curve. The galaxies that are currently still forming stars require inflows that have a flatter profile, that is, they have a sustained inflow rate compared to currently retired galaxies which show a steep decrease towards recent times. Analysing the galaxies individually we find a positive correlation between stellar mass and total inflow mass as well as a bi-modal distribution in stellar mass versus the T50 of the inflow (time to accrete 50% of the total inflow mass) similar to the SFMS in which the high T50 distribution (sustained inflow) is also predominantly star-forming and the low T50 distribution is retired.

KEYWORDS Galaxy evolution, Inflows, Stellar populations, Chemical enrichment

IAUS 373
#1622

Unraveling the young stellar populations in peculiar disk galaxies

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The inner parts of disk galaxies are rich in morphological structures such as nuclear discs, nuclear rings and bars. These structures are currently understood to form mostly out of secular dynamical processes, but can also be triggered by interaction with other galaxies. The presence of such morphological features can have a direct effect in the process of star formation of these galaxies, and of course, affect their stellar content. As a way to study these and other questions, the TIMER (Time Inference with MUSE in Extragalactic Rings, Gadotti et al. 2019) project was created. By making use of the MUSE integral-field spectrograph at VLT, observations of 21 massive, barred disk galaxies in the local Universe make available an exquisite set of high signal-to-noise, high spatial resolution data covering the visible spectral range. All the galaxies in the sample have peculiar morphological features, such as star formation rings and inner disks, which makes them an unique sample to study galaxy formation and evolution. We fitted the spectra cubes using Starburst99 (Leitherer et al. 1999), a grid of models tailored towards star-forming galaxies, which allowed us to get more accurate results for ages and chemical abundances of these populations. Working with techniques such as full spectral fitting, multi-component emission lines fitting and diagnostic diagrams (BPT and WHAN), we were able to map different sources of emission, such as very young massive stars, ionized gas by AGN and gas outflows, and infer the star formation histories of these galaxies. Our preliminary results show signs of a gas outflow in the central region of NGC613, whose origins are being investigated, while the central emission of NGC5236 seems to be dominated by star formation.

KEYWORDS galaxies, star formation, stellar populations, ifu, spectral fitting

IAUS 373

#1563

Untangling quenching mechanisms by modelling metallicity evolution: Clues for merger triggered starbursts and outflow driven quenching in MaNGA post-starburst galaxies

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A large number of mechanisms, including AGN, stellar, supernovae feedback, environmental effects such as ram pressure stripping and strangulation, and internal mechanisms like morphological quenching have been proposed in recent years to explain how most galaxies, particularly the more massive ones, seem to halt their star-formation and migrate from blue, star-forming discs to red, dead ellipticals. However, there is a lack of quantitative evidence that informs on the relative importance between the mechanisms. By studying a particular type of quenched galaxies, post-starburst galaxies, which have recently gone through a strong starburst and a subsequent rapid episode of quenching within the last ~1Gyr, one can untangle these quenching mechanisms through their predicted effects on the galaxy's star-formation history and chemical evolution, which further influences their spectra when observed. After careful modelling of mock spectra from post-starburst simulations, and proposing a two-step metallicity model that allows for decoupled stellar metallicities to be recovered before and during the starburst in place of the more commonly assumed constant metallicity, we fit the SEDs of 14 post-starbursts observed by the MaNGA IFU survey. From the results we observe 9/14 galaxies experience a significant rise in stellar metallicities during the burst, which agrees with the picture described by starburst being triggered by gas-rich major mergers, along with limited external inflow of less enriched gas, allowing for substantial gas recycling within the burst before outflow occurs, leading to the rapid rise in stellar metallicity. The use of an evolving metallicity model also allows for more accurate recovery of total stellar mass, SFR, etc, crucial for improved measurements of scaling relationships such as gas-to-stellar mass and star formation efficiency.

KEYWORDS galaxy evolution, galaxy quenching, galaxy mergers, stellar metallicity evolution, SED fitting, Bayesian modelling

IAUS 373

#1507

The JWST/NIRSpec GTO programme 'The Physics of Galaxy Assembly - IFS observations of high-z galaxies'

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In this talk I will present an overview of the NIRSpec GTO programme 'The Physics of Galaxy Assembly - IFS observations of high-z galaxies', an ambitious project aimed at characterising the internal structure of distant galaxies and, therefore, to investigate the primary physical processes driving galaxy evolution across cosmic time. The NIRSpec IFS capability will provide us with spatially resolved (low and high) resolution spectroscopy in the 1 to 5 micron range of a sample of over forty galaxies and AGN at high-redshift ($3<z<9$). The main specific objectives are: to trace the distribution of star formation, to map the resolved properties of the stellar populations, to trace the gas kinematics (i.e. velocity fields, velocity dispersion) and, hence, determine dynamical masses and also identify non-virial motions (outflow and inflows), to map metallicity gradients and dust attenuation.

KEYWORDS galaxy evolution, Active Galactic Nuclei, Galaxy dynamics, ISM

IAUS 373

#1420

Evolution of star-formation property of high redshift galaxies: perceptive view from observation and simulation

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Understanding the evolution of star-formation activity of galaxies at high redshift is important in the study of structure formation and galaxy evolution. Star-formation activity of galaxies is affected by various internal and external properties, and the relative importance of each cause or origin varies largely depending on the redshift or environment of galaxies.

In this talk, I will briefly review current status of our understanding about the evolution of star formation activity of high redshift galaxies in this regards. Then I will introduce the new results of our recent investigation on this issue, in which we have analyzed the evolution of star-formation properties of galaxies at high redshift ($0.5<z<2$), and studied the effects of various properties of galaxies on it.

Our results are derived from the analysis of observational data as well as of data from galaxy formation simulation. This will encompass broad range of various properties affecting galaxies' star formation, therefore, will provide extensive understanding regarding the evolution of star-formation properties of galaxies at high redshift, especially focusing on the effect of large-scale environment surrounding over-dense structures of galaxies on galaxies' star formation.

KEYWORDS galaxy evolution, star formation, high redshift, environment, galaxy clusters, simulation

IAUS 373

#1411

Star formation history for the starburst dwarf galaxy in the Local Group, IC 10

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IC 10 as a starburst dwarf galaxy in the Local Group has a large population of newly formed stars that are massive and intrinsically very bright in comparison with other Local Group galaxies. Using the Isaac Newton Telescope with the Wide Field Camera (WFC) in the i-band and V-band, we performed an optical monitoring survey to identify the most evolved asymptotic giant branch stars (AGBs) and red supergiants (RSGs) in this star-forming galaxy, which can be used to determine the star formation history (SFH) for the galaxy.

IC 10 has significant extinction in both internal and external components as a result of being located near the galactic plane, therefore, it is impossible to directly compare the brightness of its stars with other galaxies in the Local Group. The reddening as an effective factor for obtaining the precise magnitude of stars has been corrected for all the stars using a dust map provided by Schlegel, Finkbeiner & Davis (SFD98) [1]. The $E(B-V)$ of INT sources and LPVs have mainly concentrated in ~ 1.5 mag accordingly with RV = 3.1 extinction curve, therefore, it is consistent with the large reddening for IC 10 due to being located at low galactic latitudes. We also estimated the percentage of contamination of IC 10 sources by foreground stars at ~ 7%, then we removed them from our catalog.

To obtain the SFH for IC 10, we identified LPVs using their pulsational instability measurements within two half-light radii (2rh) from the center of IC 10. Then, we calculated the luminosity function to reconstruct the SFH using our identified 430 LPVs. After extinction correction for stars, we estimated the recent star formation rate (SFR) at ~ 0.2 $M_\odot$/yr for a constant metallicity Z = 0.0008, showing the galaxy is currently undergoing high levels of star formation. Also, a total stellar mass of 3×108 $M_\odot$ is obtained within 2rh for a constant metallicity Z = 0.0008.

References

[1] Schlegel, D. J., Finkbeiner, D. P., & Davis, M. 1998, ApJ, 500, 525.

KEYWORDS Dwarf galaxies, IC 10, Star formation history, Long-period variable stars, Reddening

IAUS 373

#1346

Search for Milky Way's magnetized circumgalactic clouds using Faraday rotation

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High-velocity clouds (HVCs) around the Milky Way provide direct evidence of ongoing gas accretion that could fuel the future star formation activity of the Galaxy. Whether the clouds are capable of delivering cold gas to the Galaxy depends on whether they survive their passage through the hostile circumgalactic gas environment. Theories and numerical simulations predict that the magnetic field significantly affects the efficiency of the mixing at the cloud-halo interface, which could in the long run affect the survival of the clouds. There have been active searches for magnetized HVCs using polarization observations and indeed a number of high-velocity complexes are suggested to be linked with magnetic fields. In this presentation, I will revisit possible obstacles in detecting magnetized HVCs using Faraday rotation and discuss how future polarization surveys will bring improvements to the situation. We test conditions of the detection using a state-of-the-art cosmological simulation, IllustrisTNG. With increased sensitivity and the polarized source density, future polarization surveys (e.g., POSSUM) will open up opportunities for the detection of magnetized HVCs down to smaller and distant systems. Our work provides insight on how to find magnetized HVCs as the first step toward understanding the role of magnetic fields on the evolution of gas clouds and the future star formation in the Galaxy.

KEYWORDS Circumgalactic medium, Milky Way, Magnetic field, Radio astronomy, Numerical simulation, Faraday rotation, Gas accretion

IAUS 373
#1164

The interplay of internal and external processes in the buildup of disk galaxies: thick and thin-disk star-formation histories in AURIGA simulations

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Galactic internal structures are important tracers of the global-galaxy formation and evolution. In particular, the spatially-resolved stellar-population analysis of massive galactic disks allows us to draw the spatial and temporal distribution of star formation during the mass assembly of disk-dominated galaxies. Properties of thick disks, old and metal poor, trace the early stages of galaxy formation, while younger metal-rich thin disks tell us about later evolutionary phases. Recent integral-field spectroscopy observations have revealed that thick- and thin-disk star-formation histories are regulated by the interplay of internal and external processes. However, the balance between direct accretion of ex-situ stars and in-situ star formation, that can occur from both gas enriched via internal chemical evolution and from more-pristine accreted gas, is still uncharted waters. Only the comparison with state-of-the-art numerical simulations, recording the full movie of galaxy evolution, can provide the Rosetta Stone to interpret the observable properties more in depth. We present edge-on maps of the stellar age, metallicity and [Mg/Fe] abundance of 27 Milky Way-mass galaxies from the AURIGA zoom-in cosmological simulations. We compare these maps to existing integral-field spectroscopic observations of edge-on disk galaxies. For each galaxy in our sample, we extract the star-formation and chemical-evolution histories of thin and thick disks, which show complex stellar populations indicating intricate formation scenarios, as previously suggested by observations. By tracking stellar and gas particles across time, we unveil the relative contributions of internal evolution and external processes such as mergers, in the formation and growth of thick and thin disks. These results provide a clear interpretation of observed properties and a recipe to understand more exhaustively future integral-field spectroscopy data of edge-on galaxies. Finally, mapping stellar-population properties at different times uncovers the transition from early star formation in the thick disk to the later growth of the thin disk, revealing the evolutionary connection between them and allowing to trace the full buildup of disk galaxies.

KEYWORDS Galaxy evolution, Star-formation history, Thick disk, Thin disk, in situ, ex situ, Accretion

IAUS 373
#1151

Modeling the FIR-radio correlation in star-forming galaxies across cosmic history

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One of the tightest correlations in astrophysics is one between the far-infrared (FIR) and the radio luminosity in star-forming galaxies that spans over ~5 orders of magnitude.

The FIR-radio correlation can be modeled phenomenologically when both luminosities are connected to star formation. The FIR emission is directly related to the star formation rate (SFR) via dust heating by young stars. Also, the radio continuum emission can be connected to the SFR, assuming that it is dominated by synchrotron emission and that both, magnetic fields and the cosmic ray population, are controlled by star formation. The latter connection is based on supernova shocks that are the source of cosmic rays and that drive interstellar turbulence which in turn amplifies magnetic fields through dynamo action. In my talk, will show how such models are successful in explaining the FIR-radio correlation observed for local star-forming galaxies.

New observations with MeerKAT indicate that the FIR-radio correlation is nearly redshift-invariant (up to z~4) but depends strongly on the stellar mass. I will present a semi-analytical galaxy model that can explain this observation. Connecting such phenomenological models with the new radio observations that cover a large redshift range potentially real novel insights into the history of galactic star formation.

KEYWORDS star formation, synchrotron emission, magnetic fields, cosmic rays, dynamos

IAUS 373
#1117

A UVIT Look at Star Formation in Nearby Interacting/Merging Galaxies

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The interactions and mergers of gas rich galaxies are known to produce star formation which often leads to nuclear activity as well. The star formation is ideally mapped using FUV and NUV emission, since UV traces star formation for longer timescales compared to other wavelengths such as Halpha emission, and over a broader stellar mass range. In this study we present FUV and NUV observations of merging and interacting galaxies in our nearby universe conducted using the UVIT. We first present a sample of merging galaxies that have have dual nuclei, whose nature varies from dual AGN to starburst pairs. The UV emission is associated with the tidal arms, individual nuclei, resonance rings, nuclear spirals as well as AGN/stellar feedback. We also find that radio emission is often closely associated with the UV emission, arising from both star formation as well as AGN activity. A correlation of nuclear radio and FUV emission also suggests kpc-scale AGN feedback. We find that a comparison of optical IFU imaging with UV imaging can reveal unique mergers such as the triple AGN system NGC7733-7734, where the UV emission traces the interaction between a small group of four galaxies. We also discuss the surprising UV/optical detection of a new diffuse galaxy UVIT2022, which was previously thought to be the tidal tail of an interacting galaxy NGC6902A, but was found to lie in forground and was previously mis-classified because of its low luminosity. Its detection demonstrates that UV is not just a powerful tool to study star formation and nuclear activity in bright merging galaxies, it can also help us detect star formation in extreme low density stellar environments, such as the metal poor, diffuse galaxy UVIT2022.

KEYWORDS Galaxies, Mergers, AGN, FUV, NUV, starformation, Feedback

IAUS 373
#1092

Mass inflows and star formation in nuclear rings of barred galaxies

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Some barred galaxies possess gaseous nuclear rings with intense star formation. To study what controls star formation in nuclear rings, we use semi-global hydrodynamic simulations in which bar-driven mass inflows are treated as boundary conditions. Our models adopt the TIGRESS framework of Kim & Ostriker (2017) to handle radiative heating and cooling, star formation, and supernova (SN) feedback. We find that when the mass inflow rate is constant or varies rapidly with timescale shorter than 50 Myr, star formation proceeds in a steady fashion with only a factor of ~2 stochastic fluctuations driven by supernova feedback. The time-averaged star formation rate (SFR) tightly correlates with the inflow rate. When the mass inflow rate varies with timescale longer than 50 Myr, on the other hand, the SFR also exhibits large-amplitude, quasi-periodic variations. In all models, the gas weight and the midplane pressure track each other closely, such that the ring maintains an instantaneous vertical dynamical equilibrium. While the SFR is determined solely by the mass inflow rate, the ring gas mass or the associated depletion time depends additionally on the background gravity and the efficacy of the SN feedback. Our results suggest that long-term, large-amplitude variations in the ring SFR are driven likely by the mass inflow rate, while short-term, small-amplitude fluctuations are due to the SN feedback.

KEYWORDS star formation, galaxy circumnuclear disk, barred spiral galaxies, stellar feedback, interstellar medium, hydrodynamical simulations, galaxy nuclei

IAUS 373
#1062

The SDSS-V Local Volume Mapper (LVM): Project Description and Status

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I will present the SDSS-V Local Volume Mapper (LVM) survey. The LVM is an ambitious project that will build the first optical integral-field spectroscopic data-cube of the Milky Way disk and the Magellanic Clouds. With its unprecedented combination of sky coverage (>2,500 square degrees) and physical spatial resolution (sub-pc in the MW and ~10 pc on the LMC/SMC), the LVM data will spatially resolve the interface between the ISM and individual sources of feedback and ionization, while providing full spectral information over the optical window (360-980 nm). The main scientific goal of the LVM is to trace the star-formation, feedback, and chemical enrichment processes that drive galaxy evolution from small energy injection scales out to galactic scales. It will do so by mapping the physical conditions of the ionized ISM (e.g. electron temperature, electron density, chemical abundances, ionization, kinematics) and connecting them to the properties of the local environment, including multi-wavelength datasets tracing colder and hotter ISM phases (e.g. HI, CO, X-rays), and the presence and spatial distribution of individual ionizing massive stars. To conduct the survey the LVM team is deploying a new facility at Las Campanas Observatory in Chile, and planning for first-light in late 2022. I will present a description of the LVM project, including the deployment of the LVM Instrument (LVM-I), the characteristics of the planned LVM survey, and will provide an update of the current project status.

KEYWORDS ISM, Star Formation, Feedback, Integral Field Spectoscopy, Surveys, Milky Way, Magellanic Clouds

IAUS 373
#1045

Investigating the Drivers of CO-to-H2 Conversion Factor Variations in Nearby Galaxy Centers

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Low-J rotational lines of ^{12}CO are frequently used to trace molecular gas in galaxies. Because of this, the CO-to-H2 conversion factor (αCO) is central to estimating the amount and properties of molecular gas. However, the value of αCO has been found to vary within and between galaxies, and the specific environmental conditions that cause these variations are not fully understood. Previous observations on ~kpc scales revealed low values of αCO in the centers of some barred spiral galaxies, including NGC 3351, NGC 3627, and NGC 4321. We present ALMA Band 3, 6, and 7 observations toward the inner ~2 kpc of these galaxies tracing ^{12}CO, ^{13}CO, and C^{18}O lines at ~100 pc resolution. With these high-resolution data, our multi-line modeling and Bayesian likelihood analysis reveal cloud-scale variations of molecular gas density, temperature, and velocity dispersion. We derive 2-10x lower-than-Galactic αCO values over the central kpc for all three galaxies, except for a ~2x higher-than-Galactic αCO in the 300 pc nucleus of NGC 3627. With our thorough analysis on NGC 3351, we show that dynamical effects resulting from turbulence/shear may lead to substantially lower αCO in the bar-driven inflows due to lower optical depth. We also find trends in αCO correlated with ^{12}CO optical depth, density, and potentially temperature. By comparing various correlations in all three galaxy centers, we are working to create observational tracers with low-J ^{13}CO lines, velocity dispersions, and/or CO isotopologue line ratios that predict the occurrence of αCO variations.

KEYWORDS barred spiral galaxies, CO line emission, molecular gas, galaxy centers, star formation

IAUS 373
#1029

Semi-analytic spectral fitting: simultaneously modeling the mass accumulation and chemical evolution in MaNGA spiral galaxies

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We develop a novel semi-analytic spectral fitting approach to quantify the star-formation histories (SFHs) and chemical enrichment histories (ChEHs) of individual galaxies. We construct simple yet general chemical evolution models that account for gas inflow and outflow processes as well as star formation. These models are fitted directly to galaxies' absorption-line spectra, while their emission lines are used to constrain current gas phase metallicity and star formation rate. We apply this method to spiral galaxies selected from the SDSS-IV MaNGA survey. By fitting the co-added absorption-line spectra for each galaxy, and using the emission-line constraints on present-day metallicity and star formation, we reconstruct both the SFHs and the ChEHs for all objects in the sample. We obtain archaeological measures of derived correlations such as the mass--metallicity relation at any redshift, which compare favourably with direct observations. We find that both the SFHs and ChEHs have strong mass dependence: massive galaxies accumulate their stellar masses and become enriched earlier. This mass dependence causes the observed flattening of the mass--metallicity relation at lower redshifts. Moreover, we are able to determine that more massive galaxies have earlier gas infall times and shorter infall time-scales, and that the early chemical enrichment of low-mass galaxies is suppressed by strong outflows, while outflows are not very significant in massive galaxies.

KEYWORDS galaxy formation and evolution, spectral fitting, star formation history, Chemical evolution

Does the star formation activity of galaxies depend on the environment?

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The effect of a galaxy's environment on its evolution and properties, including the star formation activity, has been a matter of debate for decades. Observational evidences show that galaxies inside clusters were mostly starburst and blue in the early universe. On the contrary, cluster galaxies at $z<1$ are mainly quenched and red. Does this trend arise from observational biases, or is it a consequence of the environment? To answer these questions, I will present new results from an investigation of the relationship between the star formation activity of galaxies and their environment in a large galaxy sample from the Simba cosmological simulation. We analyze the relations between the cold gas, the star formation activity, and the environment overdensity of galaxies, and how these relations vary with redshift. Our work shows that the environmental overdensity has a subtle but discernable effect on the star formation activity of galaxies. These effects are most prominent in low-mass galaxies at $0<z<1$. Among these galaxies, those in low-density regions form stars more efficiently than those in denser regions of the universe. Our work provides a theoretical framework to interpret the seemingly contradictory observational results, as well as predictions for what we can expect for upcoming wide-field galaxy surveys like JWST.

KEYWORDS Galaxy, Star formation, Galaxy environment

IAUS 373
#843

Disentangling the stellar population properties of bulges and discs in cluster galaxies

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The formation of S0 galaxies is still an open question in modern astrophysics. I present my PhD work that explores the role played by the environment in the evolution of S0 galaxies and their consituent bulges and discs. Photometric and spatially-resolved spectroscopic data are exploited for eight low-redshift clusters of galaxies from the SAMI Galaxy Survey. I analyse the colours of the bulges and the discs and their dependence on local galaxy density and on the projected cluster-centric distance. Galaxy members are explored up to 2.5 virial radii in order to investigate pre-processing in the cluster outskirts. The results point to the formation of S0 galaxies to be primarily driven by environmental processes acting in the cores of clusters and on the discs, while pre-processing plays a secondary role. In order to break the age-metallicity degeneracy that characterised the colours, I show a novel method to study the ages and metallicities of bulges and discs separately, which combines 2D photometric bulge/disc decomposition with spatially-resolved spectroscopic SAMI data. Redder bulges tend to be more metal-rich than the discs, while they can be either older or younger than the respective disc counterparts. I conclude that the redder colour in bulges is due to their enhanced metallicity relative to the discs rather than differences in age, discussing the physical interpretations in the context of formation scenarios for S0 galaxies and their bulges and discs.

KEYWORDS galaxy evolution, stellar populations, age and metallicity, bulge/disc decomposition, clusters of galaxies, IFU surveys

IAUS 373

#837

Bulge formation correlates with spin-filament alignment flips

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[2]*Department of Physics and Astronomy, Johns Hopkins University, United States of America*

The study of the interplay between galaxy angular momentum and structures in the cosmic web is a powerful tool to constrain galaxy evolution scenarios. We study the alignments of galaxy spin axes with respect to nearby cosmic web filaments as a function of various properties of the galaxies and their constituent bulges and discs. We exploit the SAMI Galaxy Survey to identify 3D spin axes from spatially-resolved stellar kinematics and to decompose galaxies into their kinematic bulge and disc components. The GAMA redshift survey is used to reconstruct the cosmic filaments. The mass of the bulge is the primary parameter of correlation with spin-filament alignments: galaxies with lower bulge masses tend to have their spins parallel to the closest filament, while galaxies with higher bulge masses are more perpendicularly aligned. Other galaxy properties, such as visual morphology, stellar age, star formation activity, kinematic parameters and local environment, show secondary correlations. The observational link between bulge growth and flipping of spin-filament alignments from parallel to perpendicular can be explained by mergers, which can drive both alignment flips and bulge formation.

The separate study of bulge and disc spin-filament alignments reveals additional clues about the formation pathways of these galaxy components: bulges tend to have more perpendicular alignments, suggesting they are merger products, while discs show different tendencies according to their kinematic features and bulge mass, pointing to multiple formation scenarios. To our knowledge, this is the first time that such a study has been conducted using observations rather than simulations. Our findings regarding formation scenarios for galaxies (and their bulges and discs), highlight the importance of integral field spectroscopy surveys for elucidating how changes in galaxy angular momentum are related to galaxy evolution within the cosmic web.

KEYWORDS galaxy evolution, galaxy kinematics, fomation of bulges and discs, bulge and disc kinematics, IFU survey, large-scale structure of Universe

IAUS 373
#829

Rapid gas accumulation on tidal-tail dwarf galaxies leads to enhanced star formation and their stabilization

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For the first time, chemo-dynamical numerical simulations of formation and growth of young tidal dwarf galaxies (TDGs) are performed with a self-consistent treatment of the tidal arm dynamics in which they are embedded. Thereby, we do not rely on idealized initial conditions, as the initial data of the presented simulation emerge from a galaxy interaction simulation. By comparing models which are either embedded in or freed from the tidal arm environment, we demonstrate the importance of the tidal arm on the evolution of TDGs because it serves as additional gas supply. The tidal arm gas is accreted and supports an enhances star formation. During the initial collapse of the proto-TDG, with a duration of a few 100 Myr, the evolution of embedded vs. isolated TDGs is indistinguishable. Significant differences appear after the collapse has halted and the further evolution is dominated by the accretion of gas and also old stars from the surrounding tidal arm. This continuous gas infall from the tidal arm in the simulation feeds the star formation of TDGs resulting in roughly a double gas mass, an increasing stellar mass by a factor of 1.5, and a more than three times higher star-formation rate compared to the isolated case. In total, a TDG grows its mass from the initial seed clump by more than one order of magnitude within a 2 billion years.

Moreover, we perform a parametric study on the influence of different environmental effects, i.e. the tidal field and ram pressure. Although TDGs' low gravitation can merely acquire Cold Dark Matter (CDM) from the massive parent galaxies due to phase-space arguments and, therefore, not be gravitationally supported by DM halos, even at high star-formation rates, surprisingly, none of the models is disrupted by extreme stellar feedback but survives over 3 billion years and more. This main message of survival, reasonably, questions their contribution to the DG population in the cosmos.

KEYWORDS dwarf galaxies, tidal dwarf galaxies, star formation

IAUS 373

#721

Testing the quenching sub-grid physics in Green Valley galaxies

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The Green Valley (GV) represents a fundamental transition stage from star-forming galaxies (in the Blue Cloud) towards quiescence (in the Red Sequence). GV galaxies are therefore important tracers of the “falling” branch of star formation. This contribution focuses on a robust, data-driven definition of GV galaxies based on the 4000A break strength, based on real galaxy data, from SDSS. We then apply the analysis to state-of-the-art cosmological simulations of galaxy formation (EAGLE and Illustris/TNG). We contrast the properties of GV galaxies to understand the behaviour of the theoretical models, and to propose improvements to the subgrid physics that controls feedback. Our methodology will be especially valuable with upcoming surveys at low spectral resolution such as Euclid or Roman.

KEYWORDS galaxy formation, galaxy evolution, stellar populations, cosmological simulations

IAUS 373
#647

The non-universal nature of hierarchical star formation in local galaxies

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The Two Point Correlation Function (TPCF) is a useful tool to probe the degree of clustering with spatial scale of a distribution of stellar populations. We use this to investigate the hierarchical distribution of young star clusters in 12 local (3--15 Mpc) star-forming galaxies using star cluster catalogs obtained with the LEGUS (Legacy ExtraGalactic UV) Survey. We compare our measured TPCFs with that of physically motivated toy models to infer the properties of the spatial distribution of star clusters in a galaxy. The sample of galaxies chosen span a range of different morphological types and physical properties, allowing us to infer the effect of the large-scale properties of the galaxy on the spatial distribution of the clusters. Our analysis shows that there are significant variations in the correlation functions among the galaxies, with the TPCF of dwarf and irregular galaxies mostly reproduced by clusters distributed randomly in an exponential disk, while spirals show power-law behaviour in the TPCF, characteristic of fractal distributions driven by scale-free turbulence. Within the sample of spiral galaxies, we find that there are significant variations in the measured fractal dimension, and the largest scale of correlated star cluster complexes, both of which show statistically significant trends with various physical properties of the galaxies (e.g. stellar mass, star formation rate etc). The results of our study suggests that the hierarchical spatial distributions of star clusters in galaxies are not universally similar, but rather dependent on the environment and evolutionary state of the galaxy it forms within.

KEYWORDS star-formation, ISM, galaxies, star-clusters

IAUS 373

#571

New era of LSST data. Estimating the physical properties of main-sequence galaxies

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The release date of the Large Survey of Space and Time (LSST) is approaching and, thanks to what will be the largest wide-field ground telescope, the Vera C. Rubin Observatory, it will provide us very high quality optical images of about 30,000 deg2 of the sky visible from Cerro Pachón in Chile. These images will result in around 15TB of data per day and, at the end of the 10 years survey, are expected to be observed around 20 billion galaxies and similar number of stars. Considering the depth of forthcoming observations, it is expected that the LSST will unveil a significant number of faint galaxies that have remained undetected in current wide-area surveys and for that will have no auxiliary data in other multiwavelenght catalogs. So the question that arises is how we can use LSST observations to obtain estimates of important properties of galaxies, and how realistic and reliable they would be.

In this work we try to answer to this question, employing simulated LSST observations to constrain the physical properties of normal star-forming galaxies, such as their star formation rate (SFR), stellar mass (Mstar), and dust luminosity (Ldust). In order to achieve this goal, we select and simulate LSST observations of 50,385 galaxies from the Herschel Extragalactic Legacy Project (HELP) survey, focusing on the COSMOS and ELAIS-N1 field. To obtain the physical properties of the galaxies, we fit their spectral energy distributions (SEDs) using the Code Investigating GALaxy Emission (CIGALE). We compared the main galaxy physical properties obtained from the fit of the observed multi-wavelength photometry of galaxies (from the UV to the far-IR) to those obtained from the simulated LSST measurements alone.

The stellar masses estimated based on the LSST measurements agree with the full UV to far-IR SED, while we obtain a clear overestimate of the dust-related properties (SFR, Ldust) estimated with LSST. We investigate the cause of this result and find that it is necessary to employ auxiliary rest-frame mid-IR observations, simulated UV observations, or the far-UV attenuation (AFUV)-Mstar relation to correct for the overestimate.

KEYWORDS Galaxies: fundamental parameters, Galaxies:photometry, infrared:galaxies, LSST, star formation rate, Spectral energy distribution fitting

IAUS 373
#519

A Unified Scenario for the Origin of Spiral and EllipticGalaxy Structural Scaling Laws

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Elliptical (E) and spiral (S) galaxies follow tight, but different, scaling laws linking their stellar masses, radii, and characteristic velocities. Mass and velocity, for example, scale tightly in spirals with little dependence on galaxy radius (the "Tully-Fisher relation"; TFR). On the other hand, ellipticals appear to trace a 2D surface in size-massvelocity space (the "Fundamental Plane"; FP). Over the years, a number of studies have attempted to understand these empirical relations, usually in terms of variations of the virial theorem for E galaxies and in terms of the scaling relations of dark matter halos for spirals. We use Lambda Cold Dark Matter (LCDM) cosmological hydrodynamical simulations to show that the observed relations of both ellipticals and spirals arise as the result of (i) a tight galaxy mass-dark halo mass relation, and (ii) the selfsimilar mass profile of CDM halos. In this interpretation, E and S galaxies of given stellar mass inhabit halos of similar mass, and their different scaling laws result from the varying amounts of dark matter enclosed within their luminous radii. This scenario suggests a new galaxy distance indicator applicable to galaxies of all morphologies, and provides simple and intuitive explanations for long-standing puzzles, such as why the TFR is independent of surface brightness, or what causes the "tilt" in the FP. Our results provide strong support for the predictions of LCDM in the strongly non-linear regime, as well as guidance for further improvements to cosmological simulations of galaxy formation.

KEYWORDS galaxies, scaling, size, velocity, tully-fisher, faber-jackson

IAUS 373
#448

Local Insights into the first stars and galaxies of the Universe

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Our understanding on how the cosmic rise of the star formation drove the galaxy and chemical evolution will be transformed by 3D spatially resolved observations of the first galaxies of the Universe. Probing individual star-forming regions in these systems are key to develop an understanding of (1) the types of stars that are prominent in the early Universe (2) how the strong ionising radiation from these stars regulated the inter-stellar-medium (ISM) and star formation properties, and (3) how supernova processes lead the cosmic chemical evolution resulting in the diversity of elements observed today. However, resolving of star-forming regions of large samples of these early systems are out of reach with current instrumentation.

In my talk I will show how we use local analogues of early galaxies to transform our knowledge of the comic dawn. Utilising 3D observations from VLT/MUSE and AAT/KOALA we probe galaxies at extreme low metallicities (defined as <10% solar) to study their star-formation and ISM properties. I will also discuss the lessons we can learn from spatially resolved studies and how we can apply them to the early Universe observations such as the deep observations planned with the JWST.

KEYWORDS galaxies, analogues, metallcity, early-galaxies

IAUS 373

#447

Insights into Monsters in the Deep: What can JWST tell us about the rise and fall of the SFR of massive quiescent galaxies at z>4?

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Deep NIR photometric surveys of the Universe such as ZFOURGE have already discovered populations of massive red galaxies in the z~4 Universe. Their existence has now been spectroscopically confirmed by deep ground based surveys. With deep NIR imaging and spectroscopy planned with JWST, number of quiescent z~>4 galaxies will only increase.The high abundance of these galaxies in the early Universe has already posed challenges to cosmological evolutionary models. They need to develop mechanisms for galaxies to (1) grow up to M*~10^10-10^11 Msol within the first 1-2 Gyrs of the Universe, (2) cease their star-formation, and (3) passively evolve them to z~0. Therefore, understanding the reasons for the rapid rise and fall of their star formation histories are of paramount importance for our cosmology.

Parts of the rest-frame optical spectrum that has so far been hidden by our atmosphere at z>4 will be uncovered by JWST/NIRSpec. Spectral features that are sensitive and well calibrated to stellar metallicity, age, and SFH fall in the near-infrared open up new insights to how these monsters formed and how they would have evolved to present time. In my talk I will discuss how we can optimally use the different observing capabilities of the instrument to obtain 2D and 3D spectroscopy of these galaxies. I will demonstrate how well we can constrain the formation histories and the limitations we will face in the era of JWST.

KEYWORDS galaxies, quiescent, high-redshift

IAUS 373
#439

The evolution of carbon-chain chemistry from prestellar to protostellar cores in Taurus Molecular Cloud

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Recent discovery of warm carbon-chain molecules in the envelope of low-mass protostars, motivates the development of the warm carbon-chain chemistry (WCCC). To understand the role of WCCC in early stage of star formation, we studied representative carbon-chain molecules, C2H and c-C3H2, in 15 sources in the Taurus Molecular Cloud, ranging from pre-stellar cores to Class I protostars, using the Submillimeter Telescope. We detect C2H in 14 sources and c-C3H2 in 13 sources. The excitation temperatures of c-C3H2 range from 5 to 11 K, where L1551 IRS 5 and L1527 have the highest temperatures. We estimate the column densities of 2.4e12-1.5e14 cm-2 and 2.6e12-2.0e13 cm-2 for C2H and c-C3H2, respectively, assuming local thermodynamic equilibrium. The column densities and abundances between the c-C3H2 and C2H are tightly correlated confirming their association in the formation pathways. Three pairs of sources, where each pair consists of a protostar and its adjacent cold envelope, provide a unique opportunity to trace the evolution of carbon-chain molecules due to temperature. From cold to warm regions, the abundance of C2H increases while that of c-C3H2 decreases. Other sources follow the same transitions, except for L1527, which is a known WCCC source. Thus, the abundance of C2H and c-C3H2 could serve as an indicator of WCCC sources. Furthermore, the bolometric luminosity, which may trace the size of the warm envelope, negatively correlates with the abundance of carbon-chain molecules, while the bolometric temperature correlates poorly with the abundances of C2H and c-C3H2. We also derive the kinetic temperature of c-C3H2 for 5 of 15 sources using RADEX, a non-LTE radiative transfer code. The kinetic temperatures range from 10 to 28 K, where L1551 IRS 5 has the highest temperature followed by L1527 with 22 K. The highest kinetic temperature among the other three sources is 14 K. While L1551 IRS 5 has c-C3H2 as warm as that in L1527, its abundance is 12.1 times lower than that in L1527, suggesting a non-WCCC origin. Interestingly, our survey shows a similar abundance of carbon-chain molecules to that of the protostars in Perseus. Follow-up observations that detect additional transitions of c-C3H2 would greatly improve our understanding on the evolution of carbon-chain chemistry from prestellar to protostellar phase.

KEYWORDS Star formation, Interstellar medium, Astrochemistry, Dense cores, Protostars, Warm carbon-chain molecules

IAUS 373
#437

Galaxy Zoo 3D: Crowdsourcing the identification of internal structure and foreground stars in MaNGA bundles

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Galaxies, particularly disc galaxies, show a wide variety of internal structures (e.g. spirals, bars, and bulges) . Mapping Nearby Galaxies at Apache Point Observatory (MaNGA, part of the fourth incarnation of the Sloan Digital Sky Surveys or SDSS-IV), has obtained spatially resolved spectral maps for 10,010 nearby galaxies selected from the SDSS Main Galaxy Sample. Many results from MaNGA have collapsed this structure into azimuthally averaged radial gradients, or symmetric 2D shapes, but there is significantly more information about the effect internal structures have on the evolution of galaxies available if we can identify different internal structures.

One of the simplest ways to identify irregular internal structures in galaxies is by visual inspection. By employing a citizen science technique to ask this question of N independent volunteers we have obtained quantitatively robust masks (and errors) for spirals and bars in MaNGA target galaxies. In addition to internal features the interface asked users to identify foreground stars and foreground/background galaxies.

I will review this project, provide a guide on how to make use of the results, and hi-light some already published, or in progress projects making use of them.

KEYWORDS galaxies, spectra, crowdsourcing, spirals, bars, MaNGA, SDSS

IAUS 373

#424

Conditions for Cool Superwinds in Massive Star-forming Regions

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Ultracompact H II regions (UC-HII) are the young, very dense cores of massive star-forming regions in dwarf galaxies, where newly formed massive stars in super star clusters are surrounded by natal molecular clouds. Thermal energies deposited into UC-HII by mechanical feedback from super star clusters can form the so-called superwinds, which can also lead to hot superbubbles due to shock-ionization, as well as coolants owing to radiative cooling. We investigate the formation of cool superwinds and hot superbubbles in UC-HII using the radiative cooling module MAIHEM in the adaptive mesh hydrodynamics program FLASH. We built a grid of hydrodynamic simulations to determine the dependence of coolants on the metallicity, mass-loss rates, kinetic heating efficiency, and ambient medium. Our hydrodynamic outputs were then used for CLOUDY models to predict UV and optical lines emitted by collisional ionized and photoionized outflow regions with various superwind parameters. Our findings could help better understand the star formation in massive star-forming regions, where cool superwinds could trigger the formation of molecular hydrogen clumpy regions.

KEYWORDS Superwinds, Superbubbles, Super Star Clusters, Radiative Cooling, Collisional Ionization, Ultra-compact H II Region, Massive Star-forming Regions

IAUS 373

#369

Characterization of synthetic panoramic surveys of the large scale structure

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We construct a cosmologicaly motivated simulation of the Dusty Star-Forming Galaxies (DSFGs) population. The simulation allows us to analyze different types of galaxies like luminous infrared (LIRGs, LIR>1011 Lsun), ultraluminous infrared (ULIRGs, LIR>1012 Lsun) and submillimeter galaxies (SMGs, SFR>100Msun/yr). The simulation covers 100 square degrees of the sky in a redshift range of z=0-7 and, because it is based on a cosmological simulation of dark matter, we have information about the distribution of galaxies throughout the cosmic web. With our simulation, we can create synthetic surveys and make predictions for the extragalactic legacy surveys that will be carried out by the new large-format multi-wavelength camera, TolTEC, installed on the 50m Large Millimeter Telescope.

In this work, we will present the methodology followed to build the simulation, as well as the results of the characterization of the areas approved for the TolTEC legacy surveys compared with observations at submillimeter wavelengths, showing good agreement between the simulation and the observations.

KEYWORDS Submillimeter Galaxies, Numerical Simulation, Galaxies, Observations, Dusty Galaxies

IAUS 373
#418

Extreme star-formation in non-extreme galaxies?

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Gamma-ray bursts (GRBs) mark the sites of extreme star-formation from a recent starburst. This should be reflected in the properties of the their host galaxies. They are in fact, highly star-forming galaxies with sub-solar metallicities and strong stellar winds. Low metallicities are needed to form the GRB progenitor and to retain its high angular momentum. Nevertheless, the GRB sites are not the extreme places we could expect and their hosts almost never fall in the class of extreme starburst galaxies. In the past years we have discovered more and more GRBs hosted in average star-forming galaxies, hence studying their immediate environment has become even more crucial. Another interesting observation is the detection of large amounts of neutral hydrogen gas in the vicinity of the GRB site. Here we present the possibly most extensive multi-wavelength dataset of a GRB host, GRB 171205A, a grand-design spiral at 160 Mpc with data from HST, MUSE, ALMA and GMRT. The GRB exploded in an outer spiral arm of the galaxy at a small star-forming region with high specific star-formation rate and low metallicity. The kinematics of the galaxy do not show any obvious signs for interactions or a recent global star-burst of the galaxy. However, the HI disk of the galaxy is very distorted with a high density in the vicinity of the GRB site. The distortion could have been caused many millions of years ago by an interaction with a distant companion. Several other examples for distorted HI distributions have been found in nearby GRB hosts. We think this might be a clue to explain the enhanced star-formation in those galaxies and the origin of the massive progenitor star.

KEYWORDS starbursts, gamma-ray bursts, HI gas, star formation triggers

IAUS 373
#365

Probing the Hidden Dimension: Constraining the Vertical Scale Height of Molecular Gas in PHANGS-ALMA Galaxies

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The vertical scale height of the ISM plays a central role in a wide range of topics including volumetric star formation laws, turbulence injection mechanisms, and assessment of the ISM dynamical state. While this quantity cannot be measured directly in most galaxies, it can be inferred from the observed gas velocity dispersion and mass distribution in these galaxies assuming hydrostatic equilibrium. I will present a large set of molecular gas scale height estimates that combine the PHANGS-ALMA CO(2-1) survey with multiwavelength ancillary data and use a new method tested against numerical simulations. Based on comparisons with these simulations, we show that the cloud-to-cloud velocity dispersion is a superior indicator of the disk scale height than the measured velocity dispersion from kpc-scale observations. Our new method fully utilizes the high spatial resolution of the PHANGS-ALMA data and yields consistent results with more direct measurements for edge-on galaxies. I will discuss key implications on the volumetric star formation laws and our general picture of the 3D gas distribution in disk galaxies. This project represents a first application of a rich multiwavelength database synthesizing key measurements from the PHANGS surveys, which will be publicly released this summer.

KEYWORDS interstellar medium, star formation laws, molecular gas, PHANGS survey, ALMA, nearby galaxies, multiwavelength database

IAUS 373

#362

The fractal structure of the young stellar population in nearby spiral galaxies

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One interesting feature of star formation in galaxies is its hierarchical scale-free spatial pattern, in which the smaller and denser young clusters are the last step in a distribution extended to kiloparsec scale regions. This spatial structure is highly likely a consequence of the turbulent mechanisms in the interstellar medium that give rise to star formation. Thus, these hierarchical patterns can reveal important clues of the star formation process.

This work presents the study of hierarchical and fractal properties of the young stellar population in a sample of 8 spiral galaxies spanning a range of distances between 2-10 Mpc, and different morphologies (e.g., flocculent and grand design spirals). We used multiband photometric data obtained with the HST and belonging to the ACS Nearby Galaxy Survey Treasury (ANGST) and Legacy ExtraGalactic UV Survey (LEGUS) programs to construct the stellar density maps, over which we detected several young stellar structures. They present a high degree of clustering and span a wide range of sizes (18–3000 pc). We found that the cumulative size distributions follow a power law shape ($N \propto S^{-\beta}$, N: number of structures, S: sizes). This suggests that star formation in the selected galaxies follows the hierarchical behaviors with characteristics of fractal distributions and values of the fractal dimensions (1.4 – 1.66).

KEYWORDS galaxies: star formation, galaxies: structure, galaxies: stellar content, stars: early-type

IAUS 373

#338

Central star formation and the inside-out growth of nuclear discs: estimating the ages of bars

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To better constrain galaxy evolution with cosmological time, one must understand which physical processes dominate at different epochs. In the early Universe, interactions and violent processes affect galaxy structure, which typically displays clumps and irregular features. In contrast, since at least redshift 1-2, the evolution of disc galaxies is predominantly driven by secular processes, characterized by the presence of bars, featuring orderly dynamics within regular structures. The transition between the dominance of these different evolutionary processes is still an open question. Since bars can regulate star formation in the central few kpcs, answering this question is key to understanding the effects of internal processes in the cosmic evolution of star formation.

Once the disc settles and is able to form the bar, tangential forces induce the inflow of the cold molecular gas to the central part of the galaxy. This gas inflow builds a rotationally-supported central structure, such as a nuclear disc, with a characteristic younger stellar population. In addition to building these structures, recent studies show that as the bar grows, the nuclear disk also grows, characterizing an "inside-out" build of the nuclear structure. Therefore, timing the nuclear structure formation allows us to time the bar formation epoch. However, such a task is not trivial, since the observed light has tangled information of the old main disc with the younger structure.

We present a new methodology to disentangle the light of the nuclear structure from the main disc. Thus, we are able to derive isolated stellar population properties of different stellar structures, such as age, metallicity, and star formation histories. The latter allows us to time the moment of the first gas inflow, related to the formation of the bar. We applied this methodology to five nearby galaxies observed with MUSE@VLT, successfully estimating the bar formation epoch. In addition, we present the smallest nuclear discs ever observed, and our results show a relation between nuclear disc radii and bar age, in accordance with the inside-out growth scenario

KEYWORDS Bar driven evolution in disc galaxies, Formation and evolution of central stellar struc, Nuclear disc, Pseudo-Bulge, Galaxy structure, Bar formation

IAUS 373

#320

Disentangling the roles of mass and environment in the quenching of galaxies since cosmic noon

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We investigate the quenching of star formation over the past 11 billion years using data from the UKIDSS Ultra-Deep Survey (UDS), which has the depth and volume required to study large numbers of galaxies across a wide range of environments. By constructing the stellar mass functions for passive galaxies in high, medium, and low-density environments out to z = 3, we find an excess of quenched galaxies in dense environments out to at least z ~ 2. Using the growth rate in the number of quenched galaxies, combined with the star-forming galaxy mass function, we calculate the probability that a given star-forming galaxy is quenched per unit time. We find a significantly higher quenching probability in dense environments (at a given stellar mass) at all redshifts. Massive galaxies (M* > 1010.7 Msolar) are ~ 3 times more likely to quench per Gyr in the densest third of environments compare to the lowest third. We conclude that environment is strongly correlated with quenching even at early times. Finally, we use post-starburst galaxies to investigate the quenching timescales, finding that a large fraction (~ 50%) of stellar mass build up in all environments is due to rapid quenching.

KEYWORDS quenching, environment, post-starburst, mass

IAUS 374
Astronomical Hazards for Life on Earth

Invited & Contributed Talks

IAUS 374

#2446

Down to Earth with geoelectric hazards from space

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Magnetic storms are caused by the dynamic action of the solar wind on the Earth's coupled magnetospheric-ionospheric system. During magnetic storms, beautiful aurorae illuminate many night-time skies. Magnetic storms can also adversely affect the infrastructure and activities of our modern, technologically-based society. Intense storms damage satellite electronics and increase satellite orbital drag, disrupt over-the-horizon radio communication, degrade the accuracy of global-positioning systems, interfere with geophysical surveys, and induce uncontrolled currents in electric-power grids, sometimes causing blackouts. In this presentation, we summarize (1) analyses of historical and modern data recording past magnetic superstorms, (2) statistical methods used to estimate the probability of the future occurrence of superstorms, (3) a project that combines Earth-surface impedance data and historical geomagnetic monitoring data to map storm-induced geoelectric hazards across the United States, and (4) deleterious impacts on North American communication and electric-power systems caused by magnetic storms. This work informs projects for improving the resilience of electric-power systems.

KEYWORDS space weather, geoelectric hazards, magnetic storms, electromagnetic induction

Astronomy for All
Busan 2022

IAUS 374

#2869

Orbit and dynamic origin of the recently recovered iron meteorite

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On November 7, 2020, at 21:27 UTC, a bright fireball was detected and instrumentally recorded over Scandinavia. The analysis of the fireball trajectory allowed us to predict an area of the fall where a 13.8 kg meteorite of iron composition was later recovered. This event became the first instrumentally documented fall of an iron meteorite.

The recorded data obtained by the Finnish Fireball Network and the Norwegian meteor camera network and its subsequent analysis allowed us to obtain accurate values of the meteoroid's orbital elements. We numerically integrated the orbital evolution of the meteoroid for 1 million years into the past using the GENGA package and found no close affinity of the meteoroid's orbit with any known near-Earth asteroid.

The determined orbit of the meteoroid allowed us to estimate the statistical possibility of its source regions using NEOPOP software. The results indicate that the meteoroid most possibly entered its near-Earth orbit via the v6 secular resonance.

From the typical values for the YORP coefficients of irregularly-shaped bodies, the derived pre-atmospheric size of the meteoroid, and the tensile strength of iron meteorites, we arrived at the YORP lifetime of the meteoroid to be at most 20 Myr. This gives the meteoroid enough time to be formed in the main belt and to travel to the near-Earth region as a separate body via the resonance. The meteoroid's orbital inclination significantly differs from the inclinations of the most prominent asteroid families in the inner part of the main belt, such as Flora, Vesta, and Nysa-Polana. This fact suggests that the meteoroid came from the non-family background asteroids dispersed in this region of the main belt. The forthcoming laboratory analysis of an estimate of isotopic abundances will result in its CRE age and can verify our predictions about the origin of the meteoroid.

The work was supported by the National Research Foundation of Ukraine (grant N 2020.02/0371 "Metallic asteroids: search for parent bodies of iron meteorites, sources of extraterrestrial resources"

KEYWORDS meteoroids, meteors, minor planets, near-Earth objects, celestial mechanics

IAUS 374
#346

ASTEROID APOPHIS AND ITS ASSOCIATED FIREBALLS

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Near-Earth asteroid (NEA) (2004MN4) Apophis has been classified as potentially hazardous due to its close approaches to the Earth and size. The age of this object is large enough for it to collide with other near-Earth objects in the past. As a result of such collisions, fragments of various sizes could be ejected from its surface. Therefore, it makes sense to search for meteors and fireballs that may have been generated by these fragments, i.e. to search for recorded meteor phenomena possibly associated with Apophis. Following the method of establishing the relationship between NEAs and fireballs/meteor showers produced by meteoroid streams (Babadzhanov et al.2013), the Everhart (1974) RADAU-19 method was used to calculate the asteroid orbital evolution over a time interval of 12 thousand years in the past. The results show that for one cycle of the perihelion argument change, the heliocentric distances of the ascending Ra and descending Rd nodes take values approximately equal to 1 AU for four values of ω. Consequently, during this period the condition of intersection of the orbits of the asteroid and the Earth is fulfilled four times. If Apophis has a related meteoroid stream, then it can produce two nighttime and two daytime meteor or fireball showers. Based on the orbital elements of asteroid Apophis corresponding to the four moments of intersection with the Earth's orbit, we calculated theoretical features of four related meteor showers. An automatized search for observed showers, individual meteors and fireballs with features close to predicted ones was performed in all published catalogs. As a result, four fireballs were found for the nighttime shower. The fireballs we found, possibly associated with asteroid Apophis, suggest that at least one collision of this asteroid with another object took place in the past, which led to the ejection of fragments from the surface of Apophis. Therefore, it is recommended to carry out meteor and fireball observations on the predicted dates of shower activity of ± 7 days in order to record meteor phenomena, possibly generated by fragments of asteroid Apophis.

References: Babadzhanov P.B., Williams I.P., Kokhirova G.I., 2013, A&A, 556, A25; Everhart E.,1974, Cel. Mech., 10, 35-55.

KEYWORDS potentially hazardous asteroid, orbit, evolution, fireball, meteoroid stream, intersection, collision

IAUS 374
#2791

The meteoroid component of the astronomical hazard to Life on Earth: contribution, relationships and more

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The ecological well-being of the Earth is closely connected with the prevention of asteroid-comet-meteoroid hazard. It is known that asteroids and comets are the parent bodies of many meteoroids. Meteoroids, which are observed as meteors in the Earth's atmosphere, always collide with the Earth. This means that the orbits of such meteoroids can be a signal for the detection of potentially dangerous larger bodies in such orbits. On the surface of the Earth, scientists are examining astroblems and meteorites as evidence of past attacks on environmental well-being from space in the form of fallen "lumps" and "stones". At the same time, the dynamics of the complex of meteoroid orbits has a intricate character. Meteor science is also engaged in unraveling the patterns of meteor orbital paths and paths of interplanetary bodies potentially dangerous for life on Earth. A separate section of meteor science is associated with the chemistry of the influx of meteor substance. The report is devoted to the analysis of the above problems, as well as related issues, using open databases of meteor orbits and others with an emphasis on radio data.

KEYWORDS Meteors, Meteoroid hazard, Life on Earth, Asteroids, Comets, Near-Earth Objects, Meteorites

IAUS 374

#2667

The Opportunity to Defend Ourselves Against Near-Earth Object Impact Threats

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Our planet has long been impacted by asteroids and comets known as near-Earth objects (NEOs). Those impacts played key roles in shaping our ancient past and giving rise to the present we now experience. We have the opportunity to understand the threats we face from future impacts and become prepared to defend ourselves against those threats. This is a unique opportunity because asteroid and comet impacts are the only natural disaster that our technology may allow us to prevent, provided that we properly develop, test, and implement effective defensive measures in advance. In this talk we will review the nature of the asteroid/comet impact threat and discuss some of the more mature asteroid/comet impact prevention techniques and systems currently under development: kinetic impactors (such as NASA's DART mission, currently in flight), standoff nuclear detonations, gravity tractors, and ion beam deflection. We will also describe the path towards becoming properly prepared to respond effectively when a threatening asteroid or comet is discovered. Finally, we will discuss the unique opportunities presented to us by NEOs. While NEOs pose an impact damage threat ranging from localized damage in cities all the way up to extinction-level events, they also represent opportunities for our species to reach new milestones of unprecedented societal significance. Developing the ability to prevent an extinction-level natural disaster is certainly one such milestone. However, asteroids and comets are also like time capsules from the era when our solar system was forming, they contain significant resources that future space explorers could utilize such as water and raw construction materials, and they are the most mission-accessible destinations outside the Earth-Moon system. Thus, asteroids and comets hold both the clues to understanding our ancient past and the keys to securing our prosperous future.

KEYWORDS asteroid, comet, planetary defense, spacecraft mission design, asteroid deflection

IAUS 374
#1076

The Pan-STARRS search for Near-Earth Objects (NEOs)

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Pan-STARRS consists of two 1.8-meter diameter telescopes located near the summit of Haleakala, on the Island of Maui, in Hawaii. Each telescope is equipped with a large camera covering a diameter of 3 degrees, and an area of 7 square degrees. These cameras are presently the largest digital cameras in the world, but will soon be surpassed by the camera of the Rubin Observatory. Each night, these telescopes search the sky for moving objects by acquiring sequences of four images, usually spaced over approximately 1 hour. Each telescope can image an area of up to 1,000 square degrees per night. All moving objects are submitted to the Minor Planet Center, and objects with unusual motion are listed on the Near-Earth Object Confirmation Page, for further observations by other telescopes. Pan-STARRS has become one of the two leading NEO discovery surveys, with the other being the Catalina Sky Survey (CSS) in Arizona. Together, these two surveys - both funded by the NASA Near-Earth Object Observations Program - account for almost 90% of new NEO discoveries, the discovery of many new comets, and many objects in the outer solar system. Pan-STARRS1 discovered the first interstellar object in 2017. Pan-STARRS is a major contributor to the discovery of larger NEOs. At the present time, approximately 40% of the 140 meter or larger NEOs are believed to have been found. The Pan-STARRS survey will be described, together with its current status, and future outlook.

KEYWORDS Near-Earth Objects, survey, asteroid, hazard, comet, interstellar

IAUS 374

#2688

Asteroid Search Program: An Initiative To Engage People for The Protection of Planet Earth

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Asteroid Impacts have been seen as one of the destructive scenarios in the history of evolution of life on earth yet it is one of the less discussed topics among students or public at large. Our team at Nepal Astronomical Society (NASO) has developed an Asteroid Search Program in order to aware, engage and discover asteroids for protecting planet earth with the use of Information and Communication Technology (ICT). Our team has been promoting Asteroid Impacts as one of the natural hazards and reaching out high school and university students and teachers to get involved in our Asteroid Search Program. Our asteroid search program has three components: Training, Campaign and Mentorship respectively. This program has been a unique initiative in Nepal started in 2016 which has already helped us to discovered many preliminary and provisional discoveries of asteroids.

This paper will discuss the impact of the program in Nepal particularly engaging youths doing asteroids search and discovering main belt asteroids including near earth asteroids. It will also share the challenges we faced during the implementation of the program and future perspective making it more accessible to youths in Nepal. It will also share the impact at the regional level in India, Bangladesh, Bhutan, Brunei and Pakistan that this program has created helping students and teachers in these countries to discover their asteroids.

KEYWORDS Asteroid Search, Use of ICT, Natural Hazard, Near Earth Asteroid

IAUS 374

#874

Jupiter and Evolution of Complex Life on Earth

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The evolution of complex life is possible only when the Earth environment is relatively stable, sans frequent dinosaur-extinction-size asteroid collisions. Jupiter plays a critical role in stabilizing Earth's environment and such role is no accident, but destined by physics. In the formative years of Earth, all planets were smaller, and there were a lot more loose objects of asteroids and comets in the solar system. Collisions with large asteroids and comets are more frequent. As these loose objects collide with and their mass merges into the larger planet, the mass of the planet increases. By its ideal location, Jupiter was destined by physics for maximum mass gain and becoming the predominant planet. Jupiter is far away enough from the sun than the inner planets that solar wind has diminished to blow away gas on the planet, and water freezes on the planet instead of vaporizing; yet close enough to the sun than the other outer planets, thus has a higher probability of colliding with loose objects. As Jupiter gets more massive, the stronger gravity pulls in more loose objects which further increases its mass. The positive feedback loop eventually turned Jupiter into the predominant planet. In the process of Jupiter becoming the predominant planet, it diverts most of the objects otherwise would hit the earth, thus providing earth a more stable environment and the condition for evolution of more complex life. Without diversion by Jupiter's massive gravity, many more comets could have collided with earth, Earth would have been completely submerged in water. Land based life and the enormous biodiversity it brings would not be possible.

KEYWORDS Jupiter, Earth, life, asteroid, comet

IAUS 374

#1168

The ESA Hera mission to the binary asteroid Didymos: NEO deflection investigation and full characterization

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The Hera mission is under development at ESA (Space Safety Program) for launch in October 2024. Hera will contribute to the first deflection test of an asteroid with the NASA DART mission within the international NASA- and ESA supported Asteroid Impact and Deflection Assessment (AIDA) collaboration.

DART will perform its impact on Dimorphos, the moon of the binary asteroid Didymos, on 26 September 2022. Before the impact, it will deploy the Italian LICIACube that will observe the impact and the following 130 seconds. Hera and its two Cubesats, Juventas and Milani, will rendezvous with Didymos in late 2026 for 6 months of investigation.

Hera will perform all the measurements necessary to understand the outcome of the DART impact on Dimorphos. In particular for the first time, internal and subsurface properties, which have great influence of the impact outcome, will be directly measured through radar sounding by the low-frequency radar onboard the Juventas Cubesat. Moreover, the direct determination the momentum transfer through Dimorphos' mass and the detailed characterization of the crater left by DART will be performed. Hera will also measure thermal properties, and with the Milani Cubesat, it will also provide compositional measurements and investigate the presence of surrounding dust. This detailed characterization, which also answers fundamental science questions, will offer with DART a fully documented deflection experiment. Numerical impact models will thus have complete data to be validated at the real scale of an asteroid, allowing the extrapolation of this new knowledge to other scenarios.

The Hera mission is the European contribution to the international effort devoted to the asteroid hazard and deflection tests. Its science legacy will extend far beyond the core aims of planetary defense and also serves as the European contribution to the international asteroid exploration era.

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KEYWORDS Planetary Defense, Binary asteroid, Deflection test, Asteroid properties, Impact outcome, Cratering

IAUS 374

#2089

After DART: Informing a Hypothetical Future Asteroid Deflection with Results from the First Kinetic Impactor Test

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NASA's Double Asteroid Redirection Test (DART) mission will, in a matter of weeks, execute a hypervelocity kinetic impact on the asteroid (65803) Didymos I Dimorphos. The results, along with detailed measurements to be made subsequently by ESA's Hera mission, are expected to demonstrate that kinetic impact can be an effective technique to deflect an asteroid from a collision with Earth. But DART is a single test on a single asteroid. A real kinetic impact deflection, should one ever become necessary, will need to be informed by extrapolation of the DART results to a situation possibly quite different from the original test. We discuss three aspects of that extrapolation: (1) Physical understanding of the ejecta response. The momentum imparted to the asteroid by escaping ejecta can exceed that of the impactor. The DART results, supplemented by Hera measurements, will jointly constrain the ejecta momentum and surface properties for one case. Extrapolating to different impact energies, momenta, and geometries, for surface materials of different densities, strengths, and porosities, is not intractable, but computationally intense. (2) Constraints on surface physical properties from imaging and spectroscopy. DART and Hera images will constrain the geomorphology of Dimorphos at small scales. Taken jointly with comparable data from other spacecraft-visited asteroids, this information can enable some physical characterization of a newly discovered object, either from Earth or from a reconnaissance spacecraft. (3) Predicting the deflection effectiveness from the inferred surface properties. In a specific deflection opportunity, orbital mechanics dictate an optimal deflection direction and magnitude. The efficiency of momentum transfer in the preferred direction is a sensitive function of impact location and topography. Hence, deflection effectiveness may be limited by the ability to obtain detailed reconnaissance and to precision-target an optimal impact site.

KEYWORDS planetary defense, asteroids, deflection, kinetic impact, DART mission, Hera mission

IAUS 374

#2066

The EU H2020 project “NEOROCKS -The NEO Rapid Observation, Characterization and Key Simulations”

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“NEOROCKS - The NEO Rapid Observation, Characterization and Key Simulations project” is an EU-funded project, started in January 2020, to address the topic c) “Improvement of our knowledge of the physical characteristics of the NEO population” of the call SU-SPACE-23-SEC-2019 from the Horizon 2020 - Work Programme 2018-2020 Leadership in Enabling and Industrial Technologies – Space.

The NEOROCKS team links up top scientists with extensive Near Earth Objects (NEOs) observation and physical characterization expertise, governmental institutions providing access to large observational facilities and data management systems, industrial partners participating in SSA programs and expertise in outreach and management. NEOROCKS connects, thus, scientific expertise, in performing observations of small Solar System bodies and the related modeling needed to derive their dynamical and physical properties, to the pragmatic planetary defense approach, which is in charge of providing operational loops and information systems to protect citizens from cosmic threats.

Therefore, NEOROCKS proposes an innovative approach to optimize observational activities, enhance modeling and simulation tasks, foster international cooperation and test response times to a possible impact threat. It also ensures the widespread availability of data and results, and engages the public through education and outreach activities. A robust and extensive data management and dissemination plan is also intended to provide the proper framework to promote international cooperation on planetary defense.

We will present a summary on the results obtained so far in the frame of the NEOROCKS project regarding physical characterization of NEOs using ground-based facilities.

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KEYWORDS Asteroids, NEO, Physical Characterization

IAUS 374
#2032

OBSERVATIONAL CHARACTERIZATION FOR THE DIDYMOS SYSTEM IN SUPPORT OF THE DART & LICIACUBE MISSION, THE FIRST KINETIC IMPACTOR DEMONSTRATION

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The NASA Double Asteroid Redirection Test (DART) is the first demonstration of a kinetic impactor on the smaller member of a binary NEA, (65803) Didymos [1]. It will impact Dimorphos, the secondary member of the Didymos binary asteroid system, in late September 2022. The mission will also carry the ASI Light Italian Cubesat for Imaging of Asteroids (LICIACube) as a piggyback [2]. The 6U CubeSat will be released in the proximity of the target and will perform an autonomous fly-by of the system, to witness the DART impact on Dimorphos, study structure and evolution of the ejecta plume to constrain impact models and characterize the non-impacted hemisphere. Scarce available data in literature for Didymos suggest a potential silicate composition, although its 1.9 μm pyroxene band is shallower than the typical silicate asteroid [3]; laboratory-calibrated relations found an affinity with L-/LL-ordinary chondrites [4], the meteorite analogues for silicate S-type bodies.

During the latest observational window in 2021 we acquired several visible spectra at Telescopio Nazionale Galileo (TNG), for the first time at different rotational phases, in order to assess the heterogeneity of the surface and to try to disentangle the contribution of primary and secondary body. The observations indicate that a subtle, but persistent spectral variability appears ([5]). Such variability is potentially connected with slightly different concentrations of olivine and hypersthene, two principal components of the L/LL-ordinary chondrites. In August 2022 we will obtain new characterization of the system in the NIR (where we have the larger uncertainty on the composition). This will be the last occasion to characterize the system prior to the DART impact in late September 2022.

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KEYWORDS NEO, DART, LICIACube, impacts

IAUS 374

#1795

LICIACube: the Light Italian Cubesat for Imaging of Asteroids part of the NASA mission DART

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LICIACube (Light Italian Cubesat for Imaging of Asteroids) [1] is a 6U CubeSat platform managed by the Italian Space Agency (ASI), that is part of the NASA mission DART [2].

At the end of September 2022 DART will impact Dimorphos, the smallest of the two asteroids forming the binary system Didymos-Dimorphos, to perform the first test of the kinetic impactor technique for planetary defense. Ten days before the impact, LICIACube will be released and guided to perform an independent fly-by of Dimorphos at around 55 km from its surface.

LICIACube is equipped with two optical cameras (with narrow and wide FoV, respectively): the primary instrument, named LEIA (Liciacube Explorer Imaging for Asteroid), is a catadioptric camera equipped with a Panchromatic filter centered at 650nm±250nm; the secondary instrument, named LUKE (Liciacube Unit Key Explorer), is the Gecko imager from SCS space, equipped with a RGB Bayer pattern filter.

The obtained images will allow us: i) to document the DART impact's effects, ii) to characterize the shape of the target, and iii) to perform dedicated scientific investigations on it.

After the Dimorphos fly-by, LICIACube will downlink the obtained images directly to Earth: the LICIACube Ground Segment has a complex architecture based on the Argotec Mission Control Centre, antennas of the NASA Deep Space Network and data archiving and processing, managed at the ASI Space Science Data Center.

Acknowledgements: The LICIACube team acknowledges financial support from Agenzia Spaziale Italiana (ASI, contract No. 2019-31-HH.0 CUP F84I190012600).

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KEYWORDS LICIACube, DART, NEO

IAUS 374

#715

We do look up: what cometary science has revealed about the potential hazards of comet and interstellar object impacts

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This talk will review the recent advances in cometary science and how they improve our capabilities to assess the potential hazards from comets and interstellar objects (ISOs) impacts. The presentation will provide an overview of the diverse comet populations in the solar system and what potential threats they could pose to Earth. We will focus on the current understanding of comets' orbital and size distributions and how they have been used to assess the probabilities of impact. The ever-improving capabilities of telescope observations and spacecraft instruments have enabled us to greatly advance our understanding of the physical properties of comets. This, in turn, provides an important input to the models predicting the survivability of comets close to perihelion, as well as the possibility of fragmentation due to sublimation or tidal forces. Additionally, the talk will discuss the relevant findings from the observations of the first two known ISOs (Oumuamua and Borisov) and how they can be extended to assess the hazard of potential ISO impacts. Finally, we will present the outlook to future observing facilities and how they would enable early discovery, better orbital and physical characterization of individual objects and an overall improved capabilities to assess the hazards of potential comet or ISO impacts on Earth.

KEYWORDS comets, interstellar objects, hazard

IAUS 374
#2515

Planetary defense activities at JAXA

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The planetary defense is an activity that deals with the problem of collisions of celestial bodies with the Earth. At present, the number of discovered near-Earth objects (NEOs) has increased to about 30,000 and discussions on the issue of the planetary defense have also become active internationally. In this situation, JAXA is also engaged in various activities related to the planetary defense. At first it is important to discover hazardous celestial bodies that collide with the Earth. In JAXA, we have developed a method called the stacking method in order to discover small and fast moving asteroids passing near the Earth. Using this method, JAXA has succeeded in discovering 11 NEOs by a small telescope with a diameter of about 20 cm. The discovery contains four 10m-class objects. JAXA also has the Bisei Spaceguard Center, which is equipped with a telescope with a diameter of 1 m. It is also important to avoid the Earth collision, when a celestial body that collides with the Earth is discovered. There is much debate about collision avoidance methods, but in any case it is important to know the characteristics of the colliding asteroids. JAXA sent the spacecraft Hayabusa and Hayabusa2 to asteroid Itokawa and Ryugu to investigate these objects, which are NEOs. As a result, we found that these asteroids have rubble pile structure, which is important information for planetary defense. For Hayabusa2, an extended mission is being carried out, and after a flyby of 2001 CC21in 2026, it will arrive at 1998 KY26 in 2031. These two asteroids are also NEOs, and in particular, 1998 KY26 is estimated to be about 30 m in size. Since such small body collisions with the Earth could actually occur in the near future, the exploration results are important from the point of planetary defense. In addition, JAXA will cooperate in Hera, a planetary defense mission of ESA, by providing an infrared camera. Hera will investigate an asteroid after NASA's DART spacecraft will collide to it.

KEYWORDS Planetary defense, Near earth object, asteroid, Hayabusa2, Hera

IAUS 374

#1771

The Many Comets of NEOWISE

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As the Near-Earth Object Wide-field Infrared Survey Explorer (NEOWISE) reactivated mission enters its ninth year of operations, it has observed over 230 cometary bodies. The WISE spacecraft was reactivated in 2013 and survey operations were restarted with the express purpose of searching for and characterizing solar system objects. Re-named NEOWISE, the spacecraft continues to image the sky for Near-Earth objects and other small bodies at wavelengths of 3.4 and 4.6 μm. These observations yield a remarkable scope of measurements of many properties related to cometary behavior. Measurements including dust production and CO+CO2 gas production, as well as cometary nucleus sizes, have been obtained using the imaging data in the two infrared channels. With approximately 91 short period and 140 long period comets observed to date, a significant sampling of the basic comet populations reside within this dataset. We will describe the sample of comet observations by NEOWISE and highlight some of the major results obtained by the survey regarding these active bodies.

KEYWORDS comets, small bodies, infrared

IAUS 374

#2788

Optimization of Gauss Method to describe with most accuracy the orbits of Near Earth Asteroids - NEAs

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In this work, the Gauss's method for inferring the orbits of minor bodies in the Solar System is revised, as well as the identification of optimization parameters and their adaptation using data from Gaia Data Release 2 for asteroids that have already been identified and named by the Minor Planet Center. We did an analysis of degrees of statistical correlation between distributions of points corresponding to the orbital elements obtained and orbital elements inferred by the Jet Propulsion Laboratory - JPL. A sample of 4 bodies is selected to which the method is applied to obtain the orbital elements and reconstruct their orbits incorporating the optimization parameters. By crossing data with the orbital parameters of the Small-Body Database (JPL), the degrees of efficiency of the method are analyzed by statistical comparison with the state vector method between orbital elements inferred with the implemented method and those accepted by the community. In the first phases of implementation of the code, it was found that the restrictions of the traditional method are overcome under the additional parameters that are proposed, resulting in orbits that are better approximated than those determined by NASA Team at the time of observation corresponding to the collection of data for the different bodies analyzed in the framework of this work. Finally, it should be noted that our method could contribute to the estimation of orbits for minor bodies of the Solar System from observational data, which could easily be taken by using small telescopes. Thus, it would enrich processes that seek to expand the coverage of observatories focused on estimating the orbits of minor bodies in the solar system.

KEYWORDS Gauss's Method, Gaia DR2, NEAs

IAUS 374

#2345

Solar hazards on different time scales

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The Sun is not a static entity that just produces energy for us. It has both short-term variability that can threaten our technology-based civilization and long-term changes that can seriously influence our climate.

On the short time-scale the Sun produces short, intense flashes of energy, and ejects huge clouds of high speed magnetised plasma. If these flares and coronal mass ejections are directed towards the Earth, they can have disastrous effects on satellites orbiting the Earth, interfere with the communications and GPS signals, and cause serious health hazard to astronauts. Associated intense and highly variable electric current systems can also couple to the high-voltage power grids and cause severe blackouts. If a flare tantamount to the largest events ever observed on the Sun would occur now, and be directed towards the Earth, the damage to our technological installations could be unimaginable and the costs could rise to trillions of Dollars.

On the long time-scale the Sun, like any star, undergoes evolution. Towards the end of its life the Sun will become a red giant that could completely engulf the Earth. However, even during its Main Sequence lifetime the Sun will become steadily brighter and change our climate.

In this talk I will briefly introduce the solar hazards induced both by the short-term and long-term effects.

KEYWORDS

IAUS 374
#688

The Fate of planet Earth

Eva Villaver[1]

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Once the Sun exhaust hydrogen as nuclear fuel it will experience a series of dramatic events that will affect the orbit of our planet. During the future giant phases of the Sun the closer orbital distance will trigger tidal forces that combined with stellar winds will determine the survival of the Earth. Under some fine-tune of the parameterization of tidal interaction and mass-loss the Earth might scape engulfment during Red Giant Phase but it will still need to survive a second giant phase of the star but this time with stronger winds. As a consequence, of the change of the stellar conditions a renewed habitable zone will appear in the outskirts of the Solar System. Stellar winds, strong irradiation, tidal forces, dynamical instability are some the effects that our Solar System will have to endure as the Sun evolves off the Main Sequence. We will summarize the effects that the evolution of the Sun is expected to have on the future fate of our planet.

KEYWORDS Stars:AGB, planetary Nebula, white dwarfs, planets, dynamical evolution

IAUS 374
#1035

The Supernova Threat to Life in the Universe

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Supernova explosions have been recognized as a potential threat to life on Earth and elsewhere. The emission of high-energy photons and charged particles (referred to as "cosmic rays") is expected to lead to a host of potential impacts, including severe depletion of stratospheric ozone (on planets with oxygen atmospheres) followed by increased stellar UV flux at the planet's surface; direct irradiation from cosmic ray secondaries (especially muons); increased lightning and wildfires; and climate changes. The severity of effects depends on the total energy received as well as spectral characteristics of the received radiation. I will review past and current work to quantify these effects and discuss connections to the history of life on Earth.

KEYWORDS supernova, life, cosmic rays, ozone

IAUS 374

#397

Lunar Impact Events by SLIO in 2020

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Sharjah Lunar Impact Observatory (SLIO) is known to be the only source of lunar impact observations in the Middle East and North Africa region. The Observatory was established in 2020 and is located in the Sharjah Academy of Astronomy, Space Sciences and Technology, University of Sharjah, Sharjah, United Arab Emirates with coordinates 25°17'02.1"N 55°27'48.4"E, with an altitude of 80 m above the sea level.

We present of 5 lunar impact events that has been recorded in 2 years of operation, the associated properties of the events were deduced from comprehensive analysis in which we have recorded apparent magnitudes of 7.94, 8.92, 9.54, 10.06, and 7.79 respectively and durations of 0.04, 0.08, 0.08, 0.04, 0.08 seconds respectively.

To reach these results, we have attached a high-sensitivity 902H Ultimate Watec video camera with a 0.5” monochrome CCD Sony ICX439ALL sensor to a 14” LX 200 ACF Schmidt-Cassegrain f/10 Meade telescope. The camera can record at 25fps with a resolution of 720 x 576 pixels and we attach an f/3.3 focal reducer to increase the field of view.

Essentially, since the Moon is the closest companion to our Earth, these meteorites represent possible dangers on the Moon as well as on Earth. Therefore, a continuous monitoring system that provides an estimation of number, size and distribution of meteorites hitting the lunar surface can greatly help predict threats to Earth where it would give information about the meteorite activity in Earth’s neighborhood which can help prevent potential disasters.

KEYWORDS Lunar Impact, SLIO, Meteor Shower, Meteorites, Observatory

IAUS 374

#1306

How It Ends

Christopher Impey[1]

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This talk explores endings, from the proximate to the distant. Humans are unlikely to be exempt from the extinction that has been the fate of all species on Earth, but we hope that it will not be by our own hand. All life on Earth, however well-adapted, will be faced with the vagaries of our cosmic environment, from wayward asteroids to dying stars. Eventually, biology will be faced with the decay of the biosphere and the death of the Sun. On longer timescales, the lights will go out in the cosmos as all stars are extinguished in the Milky Way and all other galaxies. Meanwhile, the observable universe will shrink as galaxies fly apart at ever-increasing rates, driven by enigmatic dark energy. As the eons stretch out, entropy is the victor because all galaxies will evaporate while their central massive black holes grow. The final curtain comes with the evaporation of those black holes and the decay of space-time itself. Some of these cosmic end games are subject to poorly understood physics so nobody should make any specific plans.

KEYWORDS endings, death, entropy, evaporation, catastrophes, extinction

Introducing the Cosmic Origins Of Life (COOL) model: a multi-scale, multi-physics framework for the emergence and survival of life in a hostile Universe

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Our existence is arguably the biggest multi-scale astrophysics problem. Not only does it require a comprehensive understanding of the astrophysical processes enabling the emergence of life, but also of the processes that could end it. A comprehensive answer to the problem requires linking galaxy formation and evolution, star formation, stellar feedback, and the formation and evolution of planetary systems. We will present a unified "cosmic planet population synthesis" modelling framework named Cosmic Origins Of Life (COOL), which combines prescriptions for all of these processes to self-consistently predict the emergence and persistence of habitable planets and Earth-like life across cosmic history. COOL connects state-of-the-art models for the formation of galaxies, stellar clusters, stars, and their planetary systems, accounting for the multi-scale, multi-physics environmental dependences between these. In addition, it accounts for a wide range of cosmic hazards, including the external photoevaporation and dynamical disruption of protoplanetary discs by nearby stars, dynamical perturbations of planetary systems by stellar encounters, the impact of supernova explosions and GRBs on planets, and asteroids showers, including their dependences on the evolving galactic environment. By self-consistently following stars and planets as they form and evolve within the galactic environment, the model accurately determines the occurrence rate, proximity and magnitude of these hazards for each planetary system. Using this model, we will show which astrophysical threats are the most likely to impact both the solar system and planetary systems in general, as a function of their stellar mass, age, chemical composition, and location. These insights help to answer if we live in the most fertile, benign, and suitable galactic environment and stellar system compared to other galaxies and host stars. We will conclude by discussing how COOL can inform hazard mitigation strategies.

KEYWORDS

IAUS 374
#2016

Piggybacking astronomical hazard investigations on research and development for Big Data science missions

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We are an expertise center with over a dozen astronomers and data science system experts. We have a leading role in four big data science systems for ESA and ESO instrumentation. Recently we started small projects investigating astronomical hazards for life on earth that piggyback our regular research and development of data science systems for science projects. The investigations focus on climate change and global catastrophic risks for life posed by nearby stellar encounters and solar system objects. They are performed making use of the same data science systems, their massive data archives and artificial neural networks as used for science. In this talk we describe first results and lessons learned in taking this piggybacking approach.
The synergies between the investigations in astronomical hazards and astronomical science lie in (i) common instrument and software requirements on astrometric and photometric precision calibration and (ii) common requirements on databasing and IT to handle such large datasets. The challenges in piggybacking hazard investigations on scientific missions lie in bridging the gap between communities and the sometimes non-natural fit with the traditional tasks of universities and science funding agencies. We conclude the presentation by giving an outlook on how to strengthen the synergies and overcome the challenges.
The four big data science systems all deal with complex analysis of large volumes of complex data that require precision calibration of the instruments. They are the archive and data processing system for ESA's Euclid Mission, the AstroWISE data science system supporting a dozen wide-field imagers and their surveys, the MuseWISE system for MUSE at ESO's VLT and MicadoWISE for MICADO at ESO's Extremely Large Telescope. These surveys and instruments focus on cosmology, extragalactic and Galactic science but can be used to deepen our understanding of astronomical hazards for life on earth.

KEYWORDS Astronomical Hazards, Data Science & Systems, Near-Earth Objects, Close stellar encounters

IAUS 374
#1689

ARE WE SAFE? Precovery and risk assessment of the hazardous Near-Earth Objects

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We live in a special era in the evolution of Earth's life. For the first time in about four billion years, Earth's life has the capability to detect potentially destructive Near-Earth Objects (NEOs) and defend itself against their impact. Indeed this capability is being deployed and initiatives dedicated to the detection and surveillance of hazardous NEOs have been initiated and coordinated by for example ESA's Planetary Defence Office. In this talk, I show how archival imaging data of wide-field astronomical surveys can be exploited to identify and re-assess the impact probability of these risky NEOs. As a pilot study, we performed a systematic search for the ESA risk-list NEOs appearances in archival observations of OmegaCAM. OmegaCAM is the wide-field imaging camera of the VLT Survey Telescope (VST) at ESO's Cerro Paranal Observatory and it is used for several wide-field surveys including the KiDS (Kilo-degree Survey) and VST-ATLAS surveys. While these surveys are not dedicated to the detection and surveillance of NEOs, we recover serendipitously several NEOs of the risk-list in this dataset. Interestingly, for a few cases, we identify NEOs prior to their discovery (precovery) which provides accurate positional information of NEOs at a different part of their orbit and therefore valuable compared to the existing measurements. These precoveries allow an update of the impact probability of the risky NEOs. As a result of our analysis, 3 NEOs of the risk list with sizes between 20 to 80 meters dropped out of the list. Additionally, for one NEO, the impact probability increased by a factor of 3. Motivated by this result, the talk concludes with a forward look on the value and feasibility of making life safer by expanding our approach to other archives of wide-field imaging instruments/surveys.

KEYWORDS Near-earth objects, NEO, Astronomical Surveys, Space Safety

IAUS 374

#866

What catastrophes of extraterrestrial origin can affect us on various geographical and temporal scales?

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Life on Earth can be (has been) affected by various disasters of extraterrestrial origin, such as the impacts of asteroids and comets, solar storms, the evolution of the Sun, supernova explosion, cosmic ray showers, ...

These phenomena can be grouped into catastrophes of planetary, galactic, and extragalactic origin, and finally the final destiny of the Universe.

We will list all the identified risks and compare them by the degree of affectation for Life and Humanity.

The time scales and the area on Earth impacted by each phenomenon vary considerably among them. We list the phenomena that can affect a region the size of a country, a continent, a hemisphere, or a global catastrophe. However, we note that, given the degree of economic and social interdependence at the global level, a phenomenon on a local scale can have global consequences.

The astronomical risks can be further classified in random and deterministic. Random threats are those associated with an event that has a certain probability of occurrence on a time scale, but we do not the exact date in the future, i.e.: an asteroid impact or a supernova explosion. Deterministic threats are those that will surely occur in a range of time in the future, i.e.: the evolution of the Sun into a red giant.

This comparative study will analyze what the "certainties" are (in statistical terms) about the different phenomena of extraterrestrial origin that will affect life on Earth on different geographical and temporal scales.

KEYWORDS catastrophes, impacts, asteroids, comets, solar storms, supernovae, cosmic rays

IAUS 374

#3388

The Earth-Impact Risk of Manx Comets

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Manx comets, named after the tailless Manx cat, is a new class of comets with parabolic or near-parabolic orbits. The first of its kind, C/2014 S3 (PANSTARRS), was discovered by Pan-STARRS and has a spectral reflectivity similar to inner solar system S-type asteroids, suggesting an asteroidal origin before being ejected into the Oort cloud, and eventually finding their way back into the inner solar system via the same mechanisms as long-period comets. Manx comets exhibit low or no activity, display little to no tail and are much fainter than normal long-period comets of similar size due to very low volatile activity. Earth impact velocities from Manx comets are similar to those from long-period comets, and significantly faster than from asteroids.

4000+ synthetic Earth-impacting long-period parabolic orbits were simulated to show the evolution of brightness and motion of Manx comets as they approach (with their anomalous motion, rather than cometary nature, leading to discovery). The simulations will demonstrate the relatively short warning times that are likely for this type of Earth-impactor. The Manx population was generated with a size-frequency distribution (SFD) matching that of S-type asteroids – the current SFD for Manx comets is unknown though this work is in progress [1].

2, 3 and 4-detection tracklets were created for each night that the object is visible ($V < 23.5$) from the Pan-STARRS1 observatory. The tracklets were individually evaluated through the NEO Digest2 score [2] to determine warning timescales with our current tools. The Digest2 score is considered to be a good indicator of the likelihood that an object is of a certain orbit class. Objects above the threshold score > 65 are considered to be NEO candidates.

[1] Boe, B. et al. (2019). The orbit and size-frequency distribution of long period comets observed by Pan-STARRS1. Icarus, 333, 252–272

[2] Keys, S. et al. (2019). The Digest2 NEO Classification Code. PASP, 131, 1000, Pp. 064501

KEYWORDS NEO, Manx, comets, asteroids, parabolic

IAUS 374
#3386

Is the fly-by of Gliese710 a hazard for the Solar system?

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In approximately 1.36 Myr the K-type star Gliese710 will have a close encounter with the Solar system and will pass right through the Sun's Oort cloud. Motivated by this we investigate the influence of this special stellar passage on trajectories of the small bodies orbiting there and try to answer the question, if Gliese710 could cause a higher cometary flux towards the inner Solar system.

Using a newly developed GPU-based N-body code we are able to study the motion of about 8 billion testparticles distributed in the following way: an inner disk like part (50 - 5000 au), a flared disk (5000 - 10000 au with $i < 45$ deg), and the spherical part (10000 - 100 000 au, $0 < i < 180$ deg). We concentrate on the objects residing in a cylinder around the path of the passing star.

We study the immediate influence of Gliese710 at three passage distances of 1200, 4300, and 12000 au where the star enters the Solar system in the ecliptic. Additionally, we compare this study with former results of inclined fly-bys. A huge number of comets shows significant changes of their perihelia, especially the ones directly in the path of the passing star. Some of these are even scattered to orbits with $q < 5$ au (observable region). As we do not know about the exact distribution of Oort cloud objects we can assume that the number of inward scattered objects might be non negligible.

KEYWORDS dynamics, comets, passing star

Determination of Orbital Elements of Asteroids and Gaia Astrometry

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In this study, the orbital elements of the asteroids observed in the IST 60 telescope were determined. Our results were compared with the Minor Planet Center and NASA Horizons Web-Interface results. The introduction of the Gaia space telescope provided astrometric data for many objects. We compared our results with the Gaia astrometry.

KEYWORDS Gaia, Asteroid, Astrometry

IAUS 374

#1920

How safe is Earth from long-range detection by other civilisations in the Milky way galaxy through photometric microlensing?

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To detect an Earth-analog around a solar-type star, from our current technological level, the microlensing technique which can detect distant and low-mass planets has been proven to be one of the most successful techniques. The microlensing technique allows an observer to detect a planet across Galactic distances. In the perspective of extra-terrestrial intelligence, this technique could be also used by other civilisations to detect us. We consider the photometric microlensing signal of Earth to other potential technological civilisations and call the regions of our Galaxy from which Earth's photometric microlensing signal is most readily observable as the “Earth Microlensing Zone'' (EMZ). The EMZ could represent a game-theoretic Schelling point for targeted searches for extra-terrestrial intelligence (SETI). In this work, the Gaia DR2 catalogue with magnitude G<20 is used to generate Earth microlensing probability and detection rate maps to other observers. The result shows that the Earth can be observed by extra-terrestrial observers with our current technological level. If observers are located around every Gaia DR2 star with G<20, then we expect photometric microlensing signatures from Earth to be observable by thousands of civilisations in the Galaxy per year.

KEYWORDS Graviational microlensing, Astrobiology, SETI

IAUS 374
#877

Time scale of the dynamic evolution of the NEA population: dependence on the initial orbital parameters

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An important feature of the dynamic evolution of the NEAs is that their number practically did not change over the past 2–3 Gyr as evidenced by studies of the history of crater formation on the Moon. On the contrary the dynamic scale of the NEA population, which could be characterized by tNEA, the depletion time by half, is many orders of magnitude shorter. According to the results of other authors, there are significant variations in tNEA estimates (see, e.g. a review in our paper I - Zolotarev&Shustov, Astr. Rep., 2021, V.65, p.518). It is important to know this value more precisely, since this knowledge imposes restrictions on the mechanisms of replenishment of the NEAs, the lifetime of the Main Asteroid Belt, etc. In the paper I we have estimated tNEA as 3.5 million years. We noted either that tNEA for subgroups of NEAs strongly depends on the initial orbital parameters of a subgroup.

In the current study we considered this dependence quantitively. We have integrated the orbits of all known NEAs larger than 1 km (since this sample is considered to be quite complete) for 20 Myr. We made integrations with the REBOUND software package using the MERCURIUS hybrid scheme (Rein et al., 2019, MNRAS. V.485, p.5490). All sources of NEAs were switched off. To consider dependence function tNEA (a, e, i) we divided all initial objects into 18 subgroups according to the orbital parameters. We found that tNEA is substantially higher for regions with higher inclination (i > 20o) and higher eccentricity e. There is a very strong dependence of tNEA on semi-major axis a. For a > 2.25 a.u. tNEA is an order of magnitude shorter than for groups with a < 1.5 a.u. All these dependencies are explained by a different number of close approaches of NEAs to planets.

We found that depletion of total NEO population can be approximated remarkably well with the following expression: N(t)/N0 = exp(-0.5 t0.33) where N0 – is initial number of NEAs, N(t) – is a current number of NEAs.

This study is supported by RSCF grant 22-12-00115.

KEYWORDS NEA, NEA dynamics, NEA depletion rate

IAUS 374

#2316

On the mass indices of meteor bodies

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Properties of meteor bodies (meteoroids) is a subject of great interest in view of the problems of meteor showers, cometary activity, spacecraft protection etc. Formation of meteoroid streams, physical and dynamical evolution of the streams is a topic of active discussion. One of the intriguing problems in this area is observational difference in mass indices of meteor particles for meteor showers and sporadic meteors. Let's remind that the distribution of meteoroids by mass m is described by dN/dm= m-s, where s is mass index. To reveal reasons of this observational fact we have modelled evolution of meteoroid streams consisting of particles of different masses. We consider numerically formation of an ensemble of meteoroids due to evaporation of a comet and forthcoming evolution of the ensemble experiencing both gravitational and non-gravitational effects. Comets 96P/Mahholz and 2P/Encke were considered as examples of parent bodies. Dynamics of particles of four sizes (radii) in the interval of 0.005 - 0.16 cm was studied at evolution time interval of 2 kyr. The integration of particle motion under the influence of the gravity of the Sun and planets and radiation forces was carried out according to a hybrid scheme using the REBOUND code (Rein et al., MNRAS, 485, 5490 (2019)).

Main results are: 1) for the first time, a detailed time profile of the mass index s was obtained at the intersection of a meteor shower with the Earth. A good agreement with the observations (Blauw et al. MNRAS, 414, 3322 (2011)) was noted; 2) a weak dependence on the geometry of the ejection of particles from the comet nucleus and a noticeable dependence on the ejection velocity was shown; 3) it was noted that it is critically important to know the exact time of the event (ejection) for modeling young flows. Some details of the study see in Shustov, Zolotarev, Astr. Rep., 66, 179 (2022) and Zolotarev, Shustov, Astr. Rep., 66, 255 (2022).

KEYWORDS Meteoroids, Meteors, Dynamics

IAUS 374

#1666

NAROO Program - Precovery observations of Potentially Hazardous Asteroids

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Potentially Hazardous Asteroids (PHAs) are small bodies making very close encounters with the Earth. They are a real danger and an impact may have catastrophic consequences. The knowledge of their dynamics is essential for the purpose of an international program of planetary defense. Thus, accurate astrometric measurements acquired over a large time span are important to provide reliable orbits and to detect small accelerations such as Yarkovsky effect. Photographic plates consist of a substancial source of old observations of Solar System objects. From existing databases, we identified precovery observations of PHAs which were fortuitous observations made before their discovery. We used the NAROO machine (Robert et al. 2021) to digitize the plates, and realized the astrometric reduction with Gaia eDR3 reference star catalog. We added the results to observation dataset of PHAs to define new orbital solutions and detect Yarkovsky effect with NIMA (Desmars 2013). It shows an improvement of the accuracy of their new ephemeris depending on the asteroid. Our analysis demonstrates the interest of using precovery observations from photographic plates. It will allow us to better assess the risk of PHAs in the context of Planetary Defence or Space Situational Awareness.

KEYWORDS PHAs, Dynamics, Astrometry, Precoveries, Photographic plates, NAROO, NIMA

IAUS 374
#1615

Ionospheric disturbances related to large earthquakes in North America as observed by TEC during the solar minimum

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Research studies have recently provided a convincing relationship between seismic activity and ionospheric disturbances. To investigate seismic-related ionospheric disturbances, for large earthquakes (M ≥ 5.0) in North America during the solar minimum of 2007-2010, we analyzed spatial characteristics of ionospheric disturbances using the total electron content (TEC) data, and compared them with variations in topside plasma density obtained by the Detection of Electro-Magnetic Emissions Transmitted from Earthquake Regions (DEMETER) satellite. The result showed the occurrence of positive or negative TEC anomalies around the epicenter as a precursor and successor to the earthquakes. Positive anomalies appeared more frequently and with higher magnitude than negative ones. Possible seismo-ionospheric anomalies exhibited local character in the seismic zone, whereas TEC anomalies related to the geomagnetic activity appeared over a wide range. In addition, anomalous increases in electron density measured by the DEMETER satellite over the seismic zone coincided with the TEC anomalies. Therefore, the consistency of variations in the TEC and topside electron density before and after earthquakes indicates that these ionospheric disturbances are associated with the seismic activity.

KEYWORDS seismo-ionospheric anomalies, TEC, DEMETER satellite, local TEC anomaly, seismo-ionospheric coupling

IAUS 374
#1290

NEOWISE characterization of hazardous asteroids

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The Near-Earth Object Wide-field Infrared Survey Explorer (NEOWISE) is an infrared space telescope that has been surveying the sky to find and characterize asteroids and comets coming close to the Earth. Beginning with the original WISE mission in 2010-2011, and continuing with the NEOWISE Reactivation mission since 2013, NEOWISE has been collecting thermal infrared measurements of NEOs at 3.4 and 4.6 microns. These measurements allow us to constrain the size of the observed objects, and their reflectivity when visible light measurements are available from other telescopes, allowing us to improve our assessment of the hazard they pose to Earth. To date NEOWISE has measured sizes for over 1800 NEOs, including the asteroid Apophis as part of the recent planetary defense campaign. We present an overview of the results of the NEOWISE survey of hazardous asteroids.

KEYWORDS asteroids, infrared, surveys

IAUS 374

#609

Dynamic and physical parameters of near-Earth asteroids from the observations

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We studied the dynamic and physical parameters of near-Earth asteroids from astrometric and photometric observations. We used the SBG telescope (diameter 0.4 m, focal length 0.8 m) of the Kourovka Astronomical Observatory of UrFU and the Zeiss-1000 telescope (diameter 1 m, focal length 13 m) of INASAN. We made astrometric observations in the R filter and photometric observations in the V and R filters at the SBG telescope. We carried out photometric observations in the B–V–R–I filters at the Zeiss-1000 telescope.

We improved the orbits of 9 asteroids and estimated the diurnal Yarkovsky effect acceleration for 7 asteroids using the IDA software. We estimated the periods of axial rotation: 2.7262 ± 0.0044 hour for (159857) 2004 LJ1 and 3.457 ± 0.035 hour for (326732) 2003 HB6. We obtained the color index V–R: 0.39 ± 0.08 mag for (153591) 2001 SN263, 0.44 ± 0.08 mag for (332446) 2008 AF4, and 0.40 ± 0.10 mag for 2015 NU13. We estimated the taxonomy for (159857) 2004 LJ1 and (326732) 2003 HB6 using color indices B–R and V–I. The color indices are B–R = 1.25 ± 0.10 mag and V–I = 0.82 ± 0.08 mag for (159857) 2004 LJ1, and B–R = 0.98 ± 0.05 mag and V–I = 0.89 ± 0.04 mag for (326732) 2003 HB6. We determined the taxonomy for (159857) 2004 LJ1 as S and for (326732) 2003 HB6 as D. Estimates of rotation periods, color indices, and taxonomy are consistent with the Asteroid Lightcurve Photometry Database https://alcdef.org/.

The work was supported by the Ministry of Science and Higher Education of the Russian Federation, projects: FEUZ-2020-0030 (observations with the SBG telescope and their processing), FEUZ-2020-0038 (observations with the Zeiss-1000 telescope and their processing). The following telescopes were used during the observations: SBG, which is part of the scientific equipment shared research facility “Kourovka Astronomical Observatory” of UrFU, and Zeiss-1000, which is part of the scientific equipment of shared research facility “Terskol Observatory” of INASAN.

KEYWORDS near-Earth asteroids, astrometry, photometry, rotation period, color index, taxonomy

On a nature of active asteroid Don Quixote by observations at the Sanglokh observatory

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Multicolor optical observations of active asteroid (3552) Don Quixote were carried out at the Zeiss-1000 telescope of the Sanglokh International Astronomical Observatory of the Institute of Astrophysics of the National Academy of Sciences of Tajikistan in July 2018. During observations, a sharp increase of the asteroid brightness was detected on July 14, 2018, which entailed the formation of a dust coma surrounding the object. On July 24, 2018, the asteroid magnitude approached the ephemerid value. Such a rapid drop in the magnitude means that the dust ejection and, consequently, the flare were a result of a collision of 3552 with another small object or its surface was bombarded by small meteoroids. Since the effective diameter estimated from the observations on July 23 and 24, 2018 corresponds to the currently available data, we may suppose that the collision was not catastrophic for the asteroid. However, to make this statement more convincing, new observations of the asteroid are required. The presence of frozen neutral CO2 gas in the subsurface layer of the asteroid is an established fact (Mommert et al. 2014; 2018). The value of the color index (V-R)=0.40 obtained from the observations corresponds to those for nuclei of dormant short-period comets (Licandro et al. 2008) and D-type asteroids (Dandy et al. 2015). Taking into account this fact, comet-like orbit, the low albedo value 0.02 (Veeder et al. 1989), and the detected event of reactivation of the object in July 2018, we may conclude that, with a highly probability, object 3552 is a nucleus of an extinct comet. Asteroid Don Quixote is included in the population of near-Earth asteroids, and it can be expected that, due to gravitational perturbations, it can move into the group of potentially hazardous objects. In this case, data on its nature will become essential for assessing the risks of its possible impacts with the Earth.

References: Mommert M. et al. Astrophys. J., 2014, v.781, 10 p.; Mommert M. et al. Americ.Astron.Soc., 2018, DPS meeting #50, id.505.05; Licandro J. et al. Astrophys.J.,2008, v.481, p.861; Dandy C.L. et al., Icarus,2009, v.163, p.114; Veeder G.J. et al. Astron. J., 1989, v.97,p. 1211.

KEYWORDS active asteroid, photometry, brightness, color index, diameter, extinct comet, potentially hazardous object

IAUS 374

#3288

The International Year of Planetary Defense, 2029

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The International Year of Planetary Defense 2029 (IYPD2029) will be a global raising awareness opportunity of protecting our planet Earth against possible hazards from Space, such as asteroids, the science behind it, and its contributions to ensuring human security, stimulating worldwide interest in asteroids not only as a source of information about the origins of our Universe but also about Planetary Defence and its role in keeping our planet safe and societies resilient to potential hazards from Space.

IYPD2029 will mark the monumental leap forward in a global effort in planetary defense and portray it as a peaceful global scientific endeavor that unites scientists in an international, multicultural family of scientists working together to defend our planet against the potential hazards of Near-Earth Objects. IYPD2029 is, first and foremost, an activity for the citizens of Planet Earth. It aims to convey the excitement of personal discovery, the pleasure of sharing fundamental knowledge about asteroids, comets, meteorites, Near Earth Objects and the value of the scientific culture.

The vast majority of IYPD2029 activities will take place on several levels: locally, nationally, regionally, and internationally. Several countries have already formed national committees to prepare activities for the close approach of the asteroid Apophis in 2029. These committees are collaborations between professional and amateur astronomers, science centers and science communicators. In this presentation, we aim to inform the community about the work that is underway and invite further partners to be involved and collaborate in the variety of planned efforts.

KEYWORDS planetary defense, asteroids, comets, impacts, united nations

IAUS 374
#3066

Migration of bodies to the Earth from different distances from the Sun

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Migration of bodies to the Earth from different distances from the Sun was important for formation and evolution of the Earth and the Moon from ancient to present times. Forming Earth could accumulate planetesimals from different regions of the feeding zone of the terrestrial planets [1]. The amount of water delivered to the Earth from beyond Mars's orbit could be about the mass of the terrestrial oceans [2]. The life on the Earth could not appear without water. Collisions of bodies with the Earth can kill some organisms, including people. We compared [3] the number of lunar craters larger than 15 km across and younger than 1.1 Ga with the estimates of the number of craters that could have been formed for 1.1 Ga if the number of near-Earth objects and their orbital elements during that time were close to the corresponding current values. These estimates do not contradict the growth in the number of near-Earth objects after probable catastrophic fragmentations of large main-belt asteroids, which may have occurred over the recent 300 Ma; however, they do not prove this increase. For some models, the cratering rate may have been constant over the recent 1.1 Ga. The probabilities of collisions of bodies during their dynamical lifetimes with the Earth could be up to 10-3-10-2 for some initial semi-major axes between 3.2 and 3.6 AU, whereas such probabilities did not exceed 10-5 at initial semi-major axes between 12 and 40 AU [4-5]. The work was supported by the Vernadsky Institute and by the grant 21-17-00120 of the Russian Science Foundation. [1] Ipatov S.I. Solar System Research, 2019, 53, 332-361. DOI: 10.1134/S0038094619050046. [2] Marov M.Ya., Ipatov S.I. Geochemistry International, 2021, 59, 1010–1017. DOI: 10.1134/S0016702921110070. [3] Ipatov S.I. et al. Solar System Research, 2020, 54, 384-404. DOI: 10.1134/S0038094620050019. [4] Ipatov S.I. 2020. https://doi.org/10.5194/epsc2020-71. [5] Ipatov S.I. 2021. https://doi.org/10.5194/epsc2021-100.

KEYWORDS Earth, migration, collisions, near-Earth objects

IAUS 374

#2958

Close stellar encounters with the Sun

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The nearest known star system to the Sun is currently alpha Centauri, at a distance of around 1.3 pc. But this was not always the case, and it will not remain so. For example, we know that the K7 dwarf Gliese 710 will approach within 0.1 pc of the Sun in just over a million years from now. Close stellar encounters can be a hazard to the Earth in a number of ways, in particular if they perturb comets in the Oort cloud and trigger showers of comets in the inner solar system that may impact the Earth. A highly active star could bathe the Earth in ionizing radiation, and if very unlucky, a star could go supernova as it passes by.

I will review what we know about the past and future population of stellar encounters, both statistically and for specific stars. This field of study has received a huge boost in recent years from the astrometry and radial velocities from the Gaia satellite. I will further examine how we can expect our knowledge of stellar encounters to improve in the coming years, and what the limits of that knowledge may be.

KEYWORDS stellar encounters, comets, Gaia

IAUS 374

#1667

NAROO Program - Precovery observations of Potentially Hazardous Asteroids

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Potentially Hazardous Asteroids (PHAs) are small bodies making very close encounters with the Earth. They are a real danger and an impact may have catastrophic consequences. The knowledge of their dynamics is essential for the purpose of an international program of planetary defense. Thus, accurate astrometric measurements acquired over a large time span are important to provide reliable orbits and to detect small accelerations such as Yarkovsky effect. Photographic plates consist of a substancial source of old observations of Solar System objects. From existing databases, we identified precovery observations of PHAs which were fortuitous observations made before their discovery. We used the NAROO machine (Robert et al. 2021) to digitize the plates, and realized the astrometric reduction with Gaia eDR3 reference star catalog. We added the results to observation dataset of PHAs to define new orbital solutions and detect Yarkovsky effect with NIMA (Desmars 2013). It shows an improvement of the accuracy of their new ephemeris depending on the asteroid. Our analysis demonstrates the interest of using precovery observations from photographic plates. It will allow us to better assess the risk of PHAs in the context of Planetary Defence or Space Situational Awareness.

KEYWORDS PHAs, Dynamics, Astrometry, Precoveries, Photographic plates, NAROO, NIMA

IAUS 374

#1620

New Priority List for Near Earth Objects Follow-up and prompt orbit improvement

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The simple discovery of a new Near-Earth Object does not guarantee that the information of its orbit is sufficient to exclude an imminent or close in time impact on Earth. Follow-up observations are of paramount importance in order to constrain the orbit parameters uncertainties and provide a better estimate of a possible collision.

We present a set of new tools, developed under the EU funded project NEOROCKS, which aim to support the professional and amateur observers for the activity of follow-up. The purpose is to speed up the process and allow further physical observations of the targets. This will provide a better knowledge of the target and therefore will allow better mitigation actions in case of an impacting object.

The most important achievement is the New Priority List web page (https://newton.spacedys.com/neodys2/index.php?pc=10.0), included in the NEODyS system, which is an improved version of the Priority List service provided by the Spaceguard Central Node at IAPS (see Boattini et al. 2007), but which is nowadays outdated. This talk will discuss the tecnical details of the service. The New Priority List includes also a customized email service for the observers.

Moreover, we will present the new ephemerides services and the MPC-NEO Confirmation page targets priority listing which will support a fast response for an efficient follow-up effort of the observers of just discovered objects.

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KEYWORDS NEO, Impact monitoring, Follow-up, ephemerides

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FM 1

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FM 1

#845

Event Horizon Telescope Observations of M87

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Event Horizon Telescope (EHT) is a global collaboration effort to assemble an Earth-sized VLBI network at 1mm wavelengths. With its superb angular resolution down to 25 microarcseconds, the EHT enables us to resolve and image the event-horizon-scale structures of nearby supermassive black holes (SMBH) and the innermost regions of relativistic jets in distant active galactic nuclei (AGN). In 2019, the EHT Collaboration released the first successful imaging results of the black hole shadow in the nearby radio galaxy M87. This opened a new era of observational studies of SMBH and AGN, especially on the physics of mass accretion, generation of powerful relativistic jets and general relativity. In this talk I will overview recent observational progress of EHT studies on M87, which will include total intensity and polarimetric imaging as well as efforts to coordinate multi-wavelength observations along with EHT.

KEYWORDS Active galactic nuclei, M87, Supermassive black holes, Millimeter VLBI, Relativistic jets

Magnetic Reconnection and Particle Acceleration in Relativistic Jets

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Relativistic Jets emanating from Black Holes (BH) are believed to be among the most extreme particle accelerators and very high energy (VHE) emitters in the universe. Only lately, combining theory, numerical simulations and observations, we have started to understand the potential physical processes that prevail in the surrounds of these BHs in order to explain major puzzles like the origin of the VHE gamma-ray flares, ultra-high-energy cosmic rays (UHECRs), and even polarization features of the radiation. In those inner regions, close to the jet launching region, magnetic fields are dynamically dominating and reconnection is expected to both dissipate magnetic energy and accelerate particles. In this talk, I will discuss magnetic reconnection and particle acceleration in turbulent magnetized flows and present recent results that combine three-dimensional global magnetohydrodynamic relativistic simulations with injection of test particles, showing how the particles are stochastically accelerated in the relativistic jets and accretion flows around BHs by magnetic reconnection up to ultra-high energies. Finally, I will show that these accelerated particles could explain the gamma-ray flares and associated neutrino emission observed in these sources.

KEYWORDS Magnetic Reconnection, Relativistic Jets, MHD process, black holes

FM 1

#1359

Space-VLBI view of the heart of M87 by RadioAstron at 22 GHz

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Due to its proximity and large mass of the central supermassive black hole (SMBH), M87 has been one of the prime targets to image and study compact regions where relativistic jets form in the vicinity of the black hole event horizon. Recent ground very-long-baseline interferometric (VLBI) observations at millimeter wavelengths, notably by the Event Horizon Telescope (EHT), achieved extreme angular resolutions down to ~20 microarcseconds (uas), enabling direct imaging of the black hole photon ring and the surrounding plasma. Meanwhile, space-VLBI observations at centimeter wavelengths, especially the latest RadioAstron program, can reach baseline lengths of more than several Earth diameters (EDs), thus holding great potential to probe the base of the jet close enough to the black hole.

Here we present new results from RadioAstron imaging observations of M87 at the radio frequency of 22 GHz. We have detected interferometric signals up to ~2.8 ED or ~3 Gλ fringe spacing, verified by multiple calibration methods applied on the faint ground-to-space baselines. As a result, the highest angular resolution of ~150 uas has been achieved towards M87 at this low frequency. The corresponding new image shows edge-brightened jet and counterjet structures on sub-milliarcsecond scales and intriguing morphology of the highly resolved VLBI core. In addition, we have also analyzed more space-VLBI scans of M87 from the RadioAstron AGN survey program. Analysis of these data results in tighter constraints on the source compactness, with upper limits on the correlated flux densities up to ~25 Giga wavelength fringe spacing (~8 uas resolution). Details of these results and their implications will be further discussed in this talk.

KEYWORDS galaxies: jets, galaxies: active, galaxies: individual: M87, Techniques: interferometric, Techniques: high angular resolution

FM 1

#1188

Unravelling the Innermost Jet Structure of OJ 287 with GMVA+ALMA Observations

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OJ 287 is one of the best candidates for hosting a supermassive binary black hole system and an ideal target for studying jet physics. In this talk, we will present the total intensity and polarization maps of OJ 287 at 3.5 mm obtained with GMVA+ALMA in 2017-2020. The participation of phased-ALMA significantly boosted the sensitivity and the north-south resolution of the GMVA. The high sensitivity has motivated us to image the data with the newly developed regularized maximum likelihood imaging methods, revealing the innermost jet structure with unprecedentedly high angular resolution. Our 2017 images show a compact and twisted jet extending along the northwest direction with two bends in the inner 200 microarcseconds that resemble a precessing jet in projection. An extended jet feature that lies at 200 microarcseconds northwest of the core shows a conical shape in both total and linearly polarized intensity and a bimodal distribution of the linear polarization electric vector position angle. We discuss the nature of this feature by comparing our observations with models and simulations of oblique and recollimation shocks.

We will also discuss possible jet axis changes over time and compare them with the predictions by the binary SMBH model.

KEYWORDS galaxies: jets, galaxies: active, radio continuum: galaxies, polarization

FM 1

#1142

The Intrinsic Structure of Sagittarius A* at 1.3cm and 7mm

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Sagittarius A* (Sgr A*), the Galactic Center supermassive black hole (SMBH), is one of the best targets in which to resolve the innermost region of an SMBH with very long baseline interferometry (VLBI). In this study, we have carried out observations toward Sgr A* at 1.349 cm (22.223 GHz) and 6.950 mm (43.135 GHz) with the East Asian VLBI Network, as a part of the multiwavelength campaign of the Event Horizon Telescope (EHT) in 2017 April. To mitigate scattering effects, the physically motivated scattering kernel model from Psaltis et al. (2018) and the scattering parameters from Johnson et al. (2018) have been applied. As a result, a single, symmetric Gaussian model well describes the intrinsic structure of Sgr A* at both wavelengths. From closure amplitudes, the major axis sizes are ~704±102 microarcseconds (axial ratio ~1.19) and ~300±25 microarcseconds (axial ratio ~1.28) at 1.349 cm and 6.95 mm, respectively. Together with a quasi-simultaneous observation at 3.5 mm (86 GHz) by Issaoun et al. (2019), we show that the intrinsic size scales with observing wavelength as a power law, with an index ~1.2±0.2. Our results also provide estimates of the size and compact flux density at 1.3 mm, which can be incorporated into the analysis of the EHT observations. In terms of the origin of radio emission, we have compared the intrinsic structures with the accretion flow scenario, especially the radiatively inefficient accretion flow based on the Keplerian shell model. With this, we show that a nonthermal electron population is necessary to reproduce the source sizes.

KEYWORDS supermassive black hole, Sagittarius A*, very long baseline interferometry, East Asian VLBI Network

FM 1
#1739

Collimation and Acceleration of AGN jets

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It is believed that relativistic jets in AGNs are accelerated by strong magnetic fields. The magnetohydrodynamic (MHD) models of jet acceleration predict that (i) jet is gradually collimated by the pressure of an external medium confining the jet and (ii) jet collimation and acceleration occur simultaneously. Indeed, systematic collimation has been revealed in the jet of M87 inside the Bondi radius by many recent very long baseline interferometry observations. However, both the nature of the external confining medium and the presence of gradual jet acceleration in the jet collimation zone have not been well constrained by observations. In the first part of my talk, I briefly introduce our recent study of Faraday rotation in the M87 jet, where information on the external medium is imprinted. We found that the magnitude of the Faraday rotation measure systematically decreases with increasing distance from the black hole in the jet collimation zone. Our data is consistent with a picture that substantial winds, non-relativistic un-collimated gas outflows launched from hot accretion flows, confine the jet, resulting in the observed jet collimation. In the second part, I present the results of our recent kinematic analysis of the high-cadence monitoring data observed with the East Asian VLBI Network (EAVN) and of the Very Long Baseline Array (VLBA) archival data. We found that the jet is gradually accelerated from non-relativistic to relativistic speeds over a broad distance range that coincides with the jet collimation zone, which is in good agreement with the prediction of the MHD models. I also present the results of my recent work on another nearby radio galaxy NGC 315, which shows a very similar trend of jet collimation and acceleration to M87. If time allows, I will briefly overview some of our future observational projects that may be critical for understanding of the jet collimation and acceleration process in AGNs.

KEYWORDS M87, AGN, Jet, Polarization, Kinematics, VLBI

FM 1

#2047

Jets from accretion disk dynamos: a consistent model for dynamo and resistivity

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Astrophysical jets are launched from strongly magnetized systems that host an accretion disk surrounding a central object. The origin of the magnetic field, which is a key component of the launching process, is still an open question. Here we address the question of how the magnetic field required for jet launching is generated and maintained by a dynamo process.

We performed non-ideal Magnetohydrodynamic simulations by applying the PLUTO code, in order to investigate how the mean-field dynamo and the magnetic diffusivity affect the disk and jet properties. At first we investigated a disk dynamo that follows analytical solutions of the mean-field dynamo theory, essentially based mainly on the Coriolis number. We thereby confirmed the anisotropy of the dynamo tensor acting in accretion disks, allowing both the resistivity and mean-field dynamo to be related to the disk turbulence.

Then, we studied the feedback of the generated magnetic field on the mean-field dynamo. We found that a stronger quenching of the dynamo leads to a saturation of the magnetic field at a lower disk magnetization. Nevertheless, we found that, when applying only a dynamo quenching, the overall jet properties do not depend on the feedback model.

Finally, we present a feedback model which encompasses a quenching of the magnetic diffusivity. Our modeling considers a more consistent approach for mean-field dynamo simulations, as the magnetic field quenching of turbulence should be considered for both, a turbulent dynamo and turbulent magnetic diffusivity. We find that after the magnetic field is saturated the efficient Blandford-Payne mechanism take place yielding to more collimated yet slower jets. We find strong intermittent periods of flaring and knot ejection for low Coriolis numbers. In particular, flux ropes are built up and advected towards the inner disk thereby cutting off of the inner disk wind, leading to magnetic field reversals, reconnection and the emergence of intermittent flares.

KEYWORDS MHD, Jets, Dynamo, Diffusivity, Accretion disks, Outflows

Supermassive black holes and relativistic jets: insights from simulations and Event Horizon Telescope observations

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Most supermassive black holes in the local universe are surrounded by hot, thick, and dim accretion flows. These systems can launch powerful relativistic jets that can extend to distances outside the black hole's host galaxy. The formation, collimation, and evolution of these jets has been extensively studied with General Relativistic Magnetohydrodynamic (GRMHD) simulations. These GRMHD simulations have been particularly useful in interpreting high-resolution observations from the Event Horizon Telescope (EHT). The EHT has produced images of event-horizon-scale emission at the jet base in M87; the EHT has also produced images of downstream jet structure in 3C279, OJ287, and Centaurus A. I will discuss recent insights on the black hole-jet connection from both GRMHD simulations and recent EHT observations of relativistic jets. In M87, the only GRMHD models consistent with EHT observations and the observed jet power are magnetically arrested accretion flows, where near-horizon magnetic fields are coherent, dynamically important, and extract spin energy from the black hole. Simulations predict that future EHT observations of M87 will have enough sensitivity to observe fainter emission downstream of the near-horizon emission ring. These observations will constrain plasma and magnetic field properities from the event horizon through the jet launching region.

KEYWORDS

FM 1
#3409

The filamentary structure of 3C279 probed by RadioAstron

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The EHT observed 3C279 in April 2017 at 1 mm, revealing the intriguing innermost structures present at the jet base. Comparable resolutions at centimeter wavelengths can only be achieved by extending the maximum baseline distance far beyond the Earth's diameter (ED). We will present 1 cm results obtained by a ground array of 23 antennas and the space radio-telescope RadioAstron in March 2014. With the successful detection of space-ground fringes up to 8 ED and a highly elliptical orbit perpendicular to the jet direction, we are able to probe, at angular resolutions similar to the EHT, the ultra-compact features of 3C279 close to the core and also the transverse extended jet emission. Total intensity images confirm the perpendicular nature of the core and the jet observed by the EHT and, in addition, large-scale helical filaments departing from the core and extending up to 1 mas. We interpret these filaments as produced by Kelvin-Helmholtz plasma instabilities threaded by a predominantly toroidal helical magnetic field, and propose a novel model in which moving components along the jet are a result of local changes in the properties of the plasma within the filaments as they evolve downstream the jet.

KEYWORDS

FM 1
#1817

Constraints on Particle Acceleration in Relativistic Jets from Gamma-ray observations

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Blazar type AGN are rapidly variable on timescales from Msec to ksec, implying very compact regions being the sites of considerable fractions of the radiative luminosity in a wide range of the broad-band spectra. The energy dependence of time-scales characterizing the variability patterns, deduced in a variety of different statistical methods provides constraints on the disentangles acceleration-, crossing- and cooling time-scales. Studies in the high-energy gamma ray regime are particularly well suited: The Fermi-LAT instruments provides homogeneously sampled light-curves for hundreds of sources with a dynamic range of ~ 1 decade to ~ 1 day, while ground-based gamma-ray instruments provide enough sensitivity to extend the temporal frequencies down to ~ 1ksec. This covers characteristic time-scales and enables studies of secular evolution on temporal frequencies exceeding characteristic time-scales.The constraints are affected by a significant spread in source luminosity and Doppler boost among any subset of sources suited for homogeneous studies, requiring rigid statistical tests.

We describe the methods, individual test cases and statistical results obtained from measurements obtained with the Fermi-LAT instrument, the HESS IACT array, and optical studies.

The high-frequency end of the power-density spectra do not reveal significant differences in acceleration times as expected in Fermi-type acceleration and favor models that provide single-step acceleration to very high gamma-factors, as provided by magnetic reconnection. The lack persistent lags cross-correlation studies of different energies suggests that in a single event particles are accelerated over a very wide range of maximum energies.

KEYWORDS Blazar, Variability, Gamma-ray, statistics, particle acceleration, reconnection

FM 1
#1936

The parsec-scale properties of TeV blazars

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TeVCat, the on-line catalog of TeV gamma-ray sources, currently lists 251 sources, with 84 of these being AGN. Two-thirds of these belong to the class of high-frequency peaked BL Lac objects, or HBLs. Several of these TeV HBLs have displayed remarkable variability in their TeV gamma-ray emission on time scales as short as a few minutes. Although a variety of ideas has been proposed to explain this dramatic variability, they share the common feature of bulk Lorentz factors of at least 25 for the gamma-ray emitting plasma in the relativistic jets. High bulk Lorentz factors are also typically used to model TeV blazar spectral energy distributions. On the other hand, jet morphologies, kinematics, and brightness temperatures measured from parsec-scale imaging with Very Long Baseline Interferometry (VLBI) imply at most modest Doppler boosting. This so-called "Doppler crisis" may indicate the presence of structured jets in these sources, with different regions of different Lorentz factors, for example, a fast spine and a slower layer. In this talk, we will review our work characterising the parsec-scale properties of TeV emitting HBLs, and discuss the constraints on such structured jet models from our observations.

KEYWORDS TeV gamma-rays, HBLs, VLBI

FM 1

#1694

A shock-in-jet synchrotron mirror model

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Previous work on time-dependent shock-acceleration and radiation transfer in relativistic jets has successfully reproduced many spectral variability features of blazars if flaring activity is mediated by increasingly efficient diffusive shock acceleration.

However, flaring events exhibiting a significant increase of the Compton dominance, or even "orphan" gamma-ray flares, are very difficult to reproduce in this manner, suggesting that an enhancement of an external radiation field for Compton scattering may be responsible for the gamma-ray flaring. This work therefore investigates the signatures of a synchrotron mirror model in which the synchrotron emission of electrons accelerated by a mildly relativistic shock traveling along the jet, is reflected by a cloud, and the reflected synchrotron radiation acts as target photon field for enhanced Compton scattering further down the jet. The model is applied to a recent flaring event exhibiting a significant enhancement of the Compton dominance, in 3C279.

KEYWORDS Active Galactic Nuclei, Shock acceleration, Gamma-Rays

FM 1

#2680

Physics of Relativistic Jets in Gamma-ray Bursts in the Era of Multi-messenger Astronomy

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Gravitational waves were detected in 2015 by the Advanced LIGO detectors, and the year 2017 was a remarkable year in Astronomy as we, human beings, observed the first cosmic event in both gravitational waves and electromagnetic waves, hence opening the era of multi-messenger astronomy: A gravitational wave (GW) event, GW170817, was detected nearly simultaneously with a gamma-ray burst (GRB), named the GRB 170817A, as seen by NASA's Fermi Gamma-ray Space Telescope. As the GRBs being the invaluable counterpart to the gravitational wave events, the need for understanding the physical mechanism of GRBs is compelling. The difficulties in nailing down their physical mechanism come from the facts that (1) the radiative processes involved remained so elusive as revealed by the observed shape of gamma-ray spectra, (2) there has been no clear observational clue on the composition of relativistic jets launched from the explosion, and (3) there has been no clear evidence on how far from the central engine the prompt gamma-rays of GRBs are emitted while the competing physical mechanisms predict different characteristic distances from the engine. In this talk, some of the recent important developments regarding these questions will be presented.

KEYWORDS

FM 1
#1886

Unveiling gamma-ray burst jet properties with radio observations

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Radio observations are powerful probes for understanding the afterglow of gamma-ray bursts (GRBs) and the nature of the jets that produce them. The current generation of all-sky radio surveys are now sensitive enough to contribute to these efforts and detect the radio signatures produced by the GRB jets.

In this talk, I will present results from our targeted search for GRB afterglows using the Rapid ASKAP Continuum Survey and our subsequent detection of GRB 171205A at 511 days post-burst. GRB 171205A is an exceptional event: it is the sixth-closest GRB detected, whose afterglow is the second brightest measured at gigahertz frequencies, the third-longest monitored (1500+ days post-burst) to date, and is the first long-duration GRB to show evidence for a jet-cocoon structure. I will discuss what we know so far about the event, focusing in particular on what we have inferred about the circumburst medium and jet geometry from our late-time radio and high-resolution VLBI observations.

I will also highlight our ongoing search for off-axis 'orphan' afterglow candidates, i.e. GRB afterglows without a high-energy counterpart, using a novel light curve analysis method applied on multi-epoch data from the Variables and Slow Transients ASKAP Pilot Survey. Our method improves the recall of slow transients in modern unbiased radio surveys and overcomes some of the common challenges associated with using traditional variability metrics. These searches enhance our understanding of GRB jet geometry, allowing us to constrain the beaming factor, and the diversity in the GRB population. With the improved sensitivity of current and future radio telescopes, all-sky radio surveys play an increasingly important part in enabling the investigations of GRB jet properties.

KEYWORDS gamma-ray burst, radio, transients

FM 1
#2679

First Results of the TELAMON AGN Monitoring Program In the Light of the Doppler Crisis and Neutrino Emission

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The TELAMON program is using the Effelsberg 100-m telescope to study extragalactic sources of very-high-energy photon and particle emission in the context of astroparticle physics. Specifically, we are focusing on TeV blazars and candidate neutrino-associated active galactic nuclei (AGN). Here, we present results from the first ~2 years of the program. During its pilot phase, TELAMON has covered all known TeV-detected high-synchrotron-peaked (HSP) blazars in the Northern Hemisphere, which represent the most numerous population of astrophysical sources confirmed at these exceptionally high gamma-ray energies.

We have compiled a sample of about 40 sources that are observed at a high cadence of about 2-4 weeks at high radio frequencies up to 44 GHz. Enabled by the superior sensitivity of the 100-m telescope, this setup is well suited to characterize the variability properties and to trace dynamical processes in the parsec-scale jets of HSP blazars related to (very) high-energy gamma-ray flares. Along with complementary VLBI observations, these data are used to investigate the Doppler-Crisis phenomenon which is characteristic for most sources in our sample.

The TELAMON program is further studying AGN jets within the uncertainty region of very-high-energy neutrino events reported, e.g., by the IceCube neutrino telescope. Our observations provide elusive information on the high-frequency state of candidate neutrino blazars in temporal proximity to the neutrino alert. Such data are needed to explore the growing evidence for a tight physical connection between parsec-scale radio emission of blazars and very-high-energy processes leading to associated neutrino emission.

KEYWORDS blazar, AGN, radio, neutrino

FM 1
#667

Characteristic multi-wavelength emission signatures from strong shock-shock interactions in perturbed relativistic jets

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The diffusive shock acceleration of a population of relativistic electrons on internal shocks is one of the main scenarios to account for the multi-wavelength (MWL) flux variability observed in relativistic jets of active galactic nuclei. In addition to observations of flux variability, constraints are also provided by very-long-baseline interferometry (VLBI), which shows a large variety of moving and standing emission zones with distinct behavior.

We will present a model combining relativistic magneto-hydrodynamic jet simulations (MPI-AMRVAC code) with radiative transfer (RIPTIDE code). We simulate the evolution of standing and moving emission zones in the jet and study their MWL signatures from the radio to the very-high-energy (VHE) gamma-ray band by taking into account relativistic effects (Doppler beaming and light crossing time).

We focus our attention on strong interactions between a fast moving shock and stationary recollimation shocks, to study how such events lead to a significant perturbation of the stationary jet structure. Various jet geometries and large-scale magnetic field structures are tested.

Sufficiently strong shock - shock interactions are shown to lead to the appearance of trailing components, which appear in the wake of the leading moving shock. We characterize such relaxation shocks by two observational markers, one in the radio band in the time-distance plot of bright VLBI components and one at higher frequencies under the form of « flare echoes ». Our results provide a coherent interpretation of radio VLBI observations in several radio galaxies.

KEYWORDS AGN, jets, shocks, SRMHD, radiative transfer, VLBI

FM 1

#2923

Gamma-ray bursts and their outflows: physics and implications of very high energy emission

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Gamma-ray bursts (GRBs) are the most luminous sources of electromagnetic radiation in the Universe. Although widely believed to involve collimated outflows with ultrarelativistic bulk velocities, many of their basic aspects remain poorly understood. Gamma rays at very high energy (>100 GeV) were recently detected for the first time from GRBs of different types, offering important new insight. We discuss the physics and implications of these recent developments. We also touch on comparisons with relativistic jets in other astrophysical objects, highlighting key similarities and differences.

KEYWORDS gamma-ray bursts, jets, gamma rays

Modeling the GRB jet properties with 3D general relativistic simulations of magnetically arrested accretion flows

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We investigate the dependence of the GRB jet structure and its evolution on the properties of the accreting torus in the central engine. Our models numerically evolve the accretion disk around a Kerr black hole using 3D general relativistic magnetohydrodynamic simulations. We use two different analytical hydrodynamical models of the accretion disk, based on the Fishbone-Moncrief and Chakrabarti solutions, as our initial states for the structure of the collapsar disk and the remnant after a binary neutron star merger, respectively. We impose poloidal magnetic fields of two different geometries upon the initial stable solutions. We study the formation and evolution of the magnetically arrested disk state and its effect on the properties of the emitted jet. The jets produced in our models are structured and have a relatively hollow core and reach higher Lorentz factors at an angle $\gtrsim$ 9 degrees from the axis. The jet in our short GRB model has an opening angle of up to ~ 25 degrees while our long GRB engine produces a narrower jet, of up to ~ 11 degrees. We also study the time variability of the jets and provide an estimate of the minimum variability timescale in our models, which is consistent with the observations. The application of our models to the GRB jets in the binary neutron star post-merger system and to the ultra-relativistic jets launched from collapsing stars will be briefly discussed.

KEYWORDS relativistic jets, gamma-ray bursts, magnetically arrested disk, MHD, accretion disks, accretion, black hole physics

FM 1

#2401

Universal magnetic field properties in relativistic jets from accreting objects

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Linear polarization probes the magnetic field structure in synchrotron-emitting relativistic jets. Here we analyze a large sample of jet polarization properties from active galactic nuclei (AGN) and X-ray binaries (XRBs). The data include jets from supermassive black holes, stellar mass black holes, and accreting neutron stars. The jet polarization, measured from radio, infrared and optical data, spans distances from very close to the compact object where the jet is first accelerated (from ~10 to ~10,000 R_s, where R_s is the Schwarzschild radius), up to discrete ejecta on much larger scales (up to >10^10 R_s). Although these jets have very different kinetic powers and size scales, and are launched from compact objects spanning more than nine orders of magnitude in mass, we find some global similarities that appear to be common to all source types. In particular, the magnetic field is generally tangled, with polarization levels < ~10 %, at small distances from the compact object (< 10^5 R_s), where particles are being accelerated. At larger distances, the magnetic field can be highly ordered (tens of per cent polarization at 10^5 - 10^11 R_s). This increase at around 10^5 R_s is apparent in both AGN (e.g. the MOJAVE sample) and XRBs, and may represent a universal transition in the jet properties.

From detailed, spatially resolved polarization maps, it is apparent that the highest levels of polarization, for both AGN and XRBs, are associated with shock compression at the outer edges of jets. Previously identified scaling relations, such as the Fundamental Plane of black hole activity, have demonstrated that black hole physics, and jet fluxes, scale with black hole mass. Since Schwarzschild radius increases linearly with black hole mass, here we have shown that jet magnetic field ordering also likely scales with black hole mass, providing a new, universal similarity between the jets from microquasars and those from AGN.

KEYWORDS Jets, Black holes, Active Galactic Nuclei, X-ray binaries, unification, polarization

PKS 2152-699: jet coherence after strong jet-cloud interactions

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Deep radio, optical, and X-ray data for PKS 2152-699 clearly show strong jet-cloud interactions but also show that flow integrity, and memory of flow direction, persist after both a strong kpc-scale jet interaction with a cloud in the interstellar medium of the host galaxy and a second interaction at the "High Ionisation Cloud" (HIC) in the outer part of the galaxy. Disturbed gas velocities in the HIC show momentum transfer to the cloud. X-ray gas heating shows strong energy input to the intergalactic medium on a similar scale. Further out there is evidence of a rejuvenated jet just before the northern hot spot complex, where the radio, optical, and X-ray hot spots are significantly displaced from one another. This talk will discuss the interpretation of these features in terms of the nature of the jet flow on scales > 1 kpc.

KEYWORDS jets, hotspots, feedback, jet-induced star formation

FM 1

#678

Rapidly growing supermassive black holes in extremely radio-loud galaxies

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We present the optical and infrared properties of 39 extremely radio-loud galaxies discovered by cross-matching the Subaru/Hyper Suprime-Cam (HSC) deep optical imaging survey and VLA/FIRST 1.4 GHz radio survey. The recent Subaru/HSC strategic survey revealed optically faint radio galaxies (RG) down to g_AB ~ 26, opening a new parameter space of extremely radio- loud galaxies (ERGs) with the radio-loudness parameter of log R_rest = log(f_{1.4GHz,rest}/f_{g,rest}) > 4 . Because of their optical faintness and small number density of ~1 deg^-2, such ERGs were difficult to find in the previous wide but shallow or deep but small area optical surveys. ERGs show intriguing properties that are different from the conventional RGs: (1) most ERGs reside above or on the star-forming main-sequence and some of them might be low-mass galaxies with log(Mstar/Msun) < 10. (2) ERGs exhibit a high specific black hole accretion rate, reaching the order of the Eddington limit. The intrinsic radio loudness (Rint), defined by the ratio of jet power over bolometric radiation luminosity, is one order of magnitude higher than that of radio quasars. This suggests that ERGs harbor a unique type of active galactic nuclei (AGN) that show both powerful radiations and jets. Therefore, ERGs are prominent candidates of very rapidly growing black holes reaching Eddington-limited accretion just before the onset of intensive AGN feedback.

KEYWORDS AGN, jet, HSC, VLA, radio galaxy

FM 1

#276

The origin of X-ray emission from most radio-loud quasars

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Radio-loud quasars (RLQs) are more X-ray luminous than predicted by the X-ray–optical/UV relation for radio-quiet quasars(RQQs). The excess X-ray emission depends on the properties of radio jets. We perform large-scale archival Chandra/XMM-Newton data mining to investigate the X-ray–optical/UV–radio relation of optically selected RLQs. Model selection using information criteria supports the scenario where the disk/corona instead of the jets dominate the X-ray emission, which challenges 35 years of thinking about the basic nature of the nuclear X-ray emission of RLQs. A distinct jet component is likely important for only a small portion of flat-spectrum radio quasars. The corona–jet, disc–corona, and disc–jet connections of RLQs are likely driven by independent physical processes. Furthermore, the corona–jet connection implies that small-scale processes in the vicinity of supermassive black holes, probably associated with the magnetic flux/topology instead of black hole spin, are controlling the radio-loudness of quasars. The X-ray spectral properties and the correlation between X-ray luminosity and He II emission for RLQs also support the coronal origin.

KEYWORDS Quasars, Relativistic Jets, X-ray, SMBHs

FM 1

#336

Simulating young evolving relativistic jets from supermassive black holes

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Relativistic jets from AGNs are an important driver of feedback in galaxies with an active black hole. They can impact the nearby environment over different physical scales during their lifetime, with varying effects. They first interact with the host galaxy's ISM before breaking out to larger scales, significantly affecting the galaxy's morphology and evolution. I shall present the results of our recent 3D relativistic (magneto) hydrodynamic simulations, performed on scales of several kpc, of AGN jets interacting with the ambient ISM and CGM. The young relativistic jets initially couple strongly with the turbulent ISM, before breaking out to larger scales. I will subsequently present the results of a new hybrid fluid-particle scheme to model the spectral and spatial evolution of non-thermal electrons in jets. This allows us to present a more realistic description of synchrotron emitting particles and track the impact of shock acceleration in turbulent cocoons.

KEYWORDS Relativistic jets, Galaxy evolution, MHD, Simulations

Jets and ISM interplay from the nucleus to the outskirts: the two cases of Centaurus A and Fornax A

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Relativistic jets ejected by an active galactic nucleus (AGN) can displace the gas in a galaxy, and potentially prevent it from cooling and quench star formation (negative feedback) or conversely promote it by enhancing ISM pressure (positive feedback). No consensus has yet been reached on how these disruptive, but short and stochastic events influence the host galaxy throughout its lifetime. To gain a complete picture on how AGN jets influence the host galaxy it is necessary to study feedback mechanisms from the small circum-nuclear scales (few pc) to the circum-galactic environments (>tens of kpc).

In this talk, I will show the different interplay between the radio jets and the gaseous ISM in two nearby powerful radio AGNs, Fornax A and Centaurus A. In Fornax A, continuum broadband observations (84MHz-217GHz) of the large scale lobes (~200 kpc) and inner jets (6kpc) revealed a rapid flickering of the nuclear activity, and the distribution and kinematics of the neutral, molecular and ionised gas (MeerKAT, ALMA and MUSE observations) allowed us to identify both a multi-phase outflow entrained by the radio jets, and gas clouds falling onto the nucleus, thus explaining its rapid recurrent activity (Maccagni et al. 2020,2022). Our new MeerKAT observations of Centaurus A reveal that its nuclear activity is disrupting the HI disk from the centre to the outskirts of the galaxy. In the centre, the blueshifted velocities (>200 km/s) of the HI gas detected in absorption indicate the presence of a nuclear outflow. We observe HI clouds with turbulent kinematics not only along the edges of the inner radio lobes, but also, and for the first time, in proximity of the Northern middle lobe and of the X-ray knots, ~20 kpc from the centre, and along the inner and outer filament of ionised gas (8.5 and 15 kpc from the nucleus) where positive feedback is taking place. This suggests that part of the outflowing HI is the primary fuel reservoir for the newly born star forming regions.

KEYWORDS AGN, Jets, Outflows, Neutral hydrogen, Centaurus A, Fornax A, Multi-scale feedback

FM 1

#750

Witnessing the moments of jet-cloud collisions in the young radio galaxy 3C84

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We report multi-epoch very long baseline interferometric (VLBI) observations of the compact radio lobe in the young radio galaxy 3C 84. By performing the monitoring observation with the KVN and VERA Array at 43 GHz during 2015-2016, we investigate the kinematics of the newborn bright component C3 located at the tip of the recurrent jet of 3C 84. During 2015 August-September, we discover the flip of C3 and the amount of the flip is about 0.4 mas in angular scale, which corresponds to 0.14 parsec on a physical scale. The flux density of C3 showed a monotonic increase during the observation period. The flip is in good agreement with hydrodynamical simulations of jets in a clumpy ambient medium. We further continue VLBI observations of 3C 84 during 2016-2020. The image sequence of 3C 84 reveals that the hotspot in the radio lobe showed the one-year-long frustration in 2017 within a compact region, suggesting a strong collision between the jet and a compact dense cloud. Although the hotspot and the radio lobe began to move south again after its breakout, the radio lobe showed a morphological transition from an FR II- to FR I-class radio lobe and its radio flux became fainter. This is the first detection of the dynamical feedback from the cloud to the jet where the cloud located on the jet axis significantly interferes with the jet propagation and evolution at the central 1 pc region in the active galactic nucleus.

KEYWORDS Galaxy jets, Radio hot spots, Non-thermal radiation

FM 1
#452

Ray-Tracing in Hybrid Relativistic Magnetohydrodynamic Jet Simulations: A Polarimetric Study

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Investigations on how the morphology of the jet's synchrotron emission depends on the magnetic nature of the jet's relativistic plasma are fundamental to the comparison between numerical simulations and the observed polarization of the jet. Through the use of 3D hybrid particle-fluid, relativistic magnetohydrodynamic (RMHD) jet simulations (computed using the PLUTO code) we study how the jet's synchrotron emission depends upon the morphology of the jet's magnetic field structure. To overcome the missing shock physics, i.e., synchrotron losses and diffusive shock acceleration to distinguish the relativistic jet from the cooling ambient medium, we include Lagrangian particles in our numerical simulations. The particles attributes are directly calculated and interpolated on a grid in the 3D space.

Through the application of polarized radiative transfer and ray-tracing (via the RADMC-3D code) we create Full Stokes synthetic radio maps for each magnetic field jet simulation, i.e., when the jet carries a predominantly poloidal, helical, and toroidal magnetic field. Resulting in, e.g., linearly polarized intensity maps overplotted by electric vector position angles (EVPAs - ideally perpendicular to the magnetic field lines) and circular polarization maps we are able to conclude the dominant magnetic field structure in radio loud AGN.

Magnetic field morphologies within the jet has a clear effect on the jet's synchrotron emission: a toroidal field results in an edge-brightened jet whereas a poloidal field highlights the jet's central recollimation shock associated with the radio core. The circularly polarized emission clearly exhibits two signs in the toroidal field case whereas only one sign is visible in the poloidal jet.

These numerical characteristics are supported by polarized VLBA observations. The observational data are used to create maps of AGN/blazar candidates at 15 Ghz and 22 Ghz showing a classified characteristic of the chosen numerical magnetic field.

KEYWORDS Polarization, Jets, Magnetic Fields, RMHD, Simulations, Ray-tracing

FM 1
#596

Jet-ISM interaction: observations

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AGN feedback through radio jets is more efficient when jets are sweeping out the galaxy disk. This is frequent due to the random orientation of AGN accretion disks with respect to galaxy disks.

There could be only small interaction, as in NGC 1068, or more if the jet is totally running in the galaxy plane as in IC5063, Mrk3 or NGC 4258.

When the radio jet is propagating into the ISM, it is subject to shocks and creates a cocoon of hot medium, acting as a wind and producing ram-pressure on the molecular gas. The dense clouds are shattered and teared away; after some evaporation, the cooling and clump fragmentation could occur in about 1 Myr. Dust grains can reform then and serve to catalyse rapid molecule formation. When the jet encounters frontally a dense cloud, it can be deviated, and trigger expansion from this point, perpendicular to the disk plane. There might exist also a positive AGN feedback, when jet triggers star formation.

KEYWORDS Active Galactic Nuclei (AGN), radio jet, Insterstellar medium (ISM), galaxies

Jet-ICM interaction

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We show how the swirling cold front in the core of the Perseus Cluster of galaxies may have affected the outer buoyant bubbles that originated from jets from the Active Galactic Nucleus in the central galaxy NGC1275. The Outer Northern bubble appears rotated about 45 deg from the axis defined by the inner N-S bubbles. Numerical simulations of the interaction indicate that the Outer Northern bubble may have been pushed clockwise accounting for its current location. Given the common occurrence of cold fronts in cool core clusters, we raise the possibility that the lack of many clear outer bubbles in such environments may be due to their disruption by cold fronts. We also briefly mention other jet-ICM interactions in the Perseus Cluster.

KEYWORDS Jets, ICM, Perseus Cluster

FM 1
#1813

Unveiling the physics of relativistic jets with LSST and CTA

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Relativistic jets are the most powerful manifestation of the extraordinary amount of energy released by supermassive black holes (SMBH) in the centers of Active Galactic Nuclei. The observational evidence gathered by future facilities across the electromagnetic spectrum, like the Vera C. Rubin Observatory and the Cherenkov Telescope Array (CTA), accompanied by improvements in the theoretical and numerical fields, will offer an unprecedented framework for deriving important clues on the debated issues in the physics of relativistic jets.

The Legacy Survey of Space and Time (LSST), to be conducted at the Vera C. Rubin Observatory beginning in 2024, will monitor the southern sky and beyond for ten years in six photometric bands, offering a formidable tool to study relativistic jets in AGN in a statistical way, and to address the still open questions about their variability, population and environment. The alert system will allow us to trigger follow-up observations of outstanding events, especially at high (keV-to-GeV) and very high (TeV) energies. In this context, the synergy with CTA will be fundamental. CTA is the next generation ground-based very-high-energy gamma-ray astronomy observatory, comprising more than 100 telescopes located at sites in the northern and southern hemispheres. With ten times better sensitivity that current generation gamma-ray telescope arrays, CTA will transform our understanding of the high-energy universe and represent a unique tool to probe the physics of extreme environments like SMBH, including accretion physics, jet formation, relativistic interaction processes, general relativity and new fundamental physics.

In this talk I will review the challenges and the status of the study of physics of relativistic jets with next generation facilities such as the Vera C. Rubin Observatory and the CTA.

KEYWORDS relativistic jet, supermassive black hole, CTA, LSST, AGN, Vera Rubin Observatory

New Opportunities with Next-Generation Instruments: SKA and Millimetron

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I will discuss some of the up-coming next generation radio facilities, how we could use them to study jets, and what the requirements are.

At the low frequencies SKA-LOW VLBI will introduce global interferometers at hither-to unexplored wavelengths. At the cm wavelengths SKA-MID VLBI will enhance the sensitivity of the existing work-horses. In addition, both of these instruments alone will be exquisite probes of the kilo-parsec scales. At the other extreme of the radio spectrum, VLBI with Millimetron will provide the longest baselines at the highest frequencies: 3 to 1mm.

All of these next generation instruments require different next generation calibration methods. I will review these new techniques, what they require on the instrument and network, and what they will enable.

KEYWORDS SKA, Millimetron, VLBI, jet physics, astrometry, AGN

FM 1

#1432

Potential for Very High Energy gamma-ray transient monitoring with SWGO

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The Southern Wide-field Gamma-ray Observatory (SWGO) is the proposal for a new ground-based gamma-ray instrument in the Southern Hemisphere, which will use an array of water Cherenkov-based particle detectors to provide continuous monitoring and regular scanning of a large portion of the sky at the very- and ultra-high-energies (VHE and UHE, respectively). At the lower energy side, SWGO aims to push the observational range of wide-field ground-based gamma-ray facilities down to a few hundred GeV, thus bridging the gap between space and ground-based facilities in the monitoring of the VHE sky. In so doing, SWGO could become a unique instrument in the search for short time-scale transient phenomena, being an important addition to the global network of multi-messenger astrophysics. As a consequence of this design, the study of relativistic jets, which play a fundamental role in the emission of non-thermal radiation from extra-galactic gamma-ray sources, such as blazars and Gamma-Ray Bursts (GRB), is at the core of SWGO science. In fact, the details of the jet structure and of their radiation mechanisms at the highest energies are still a matter of ongoing investigation, and the ability to further detect and monitor VHE radiation, together with simultaneous multi-messenger and multi-frequency observations, has the potential to clarify some of the open questions on the physics of these objects, with implications also to cosmology and fundamental Physics. In this contribution we will discuss the potential of SWGO to constrain the physics of the VHE emission in gamma-ray sources powered by relativistic jets, through the probing of the afterglow and prompt-phase emission of GRBs, and the continuous monitoring of the spectral evolution of blazar flares in a multi-wavelength context. We will also discuss its potential role in the global network of multi-messenger instruments.

KEYWORDS Relativistic Jets, Gamma-ray Astronomy, Ground Particle Arrays, SWGO, Blazars, GRBs

Concluding Remarks

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I will review some important results presented in this meeting to discuss what we know about relativistic jets and possible future developments.

KEYWORDS relativistic jets, AGN

e-Posters

FM 1

#3407

Enhanced Activity of Black Hole Accretion Flows during Hard-to-Soft State Transition

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Relativistic jets are ejected during hard-to-soft state transitions in black hole accretion flows. During this transition, radiatively inefficient accretion flows (RIAF) shrinks in the vertical direction by radiative cooling, and forms a disk supported by azimuthal magnetic fields (Machida et al. 2006). This disk is distinct from MAD (Magnetically Arrested Disk) supported by poloidal magnetic fields. Since strong azimuthal magnetic fields prevent the disk to collapse to a geometrically thin, standard disk, the disk stays in geometrically slim state in which magnetic heating balances with radiative cooling (Oda et al. 2009). This state corresponds to the luminous hard state observed in stellar mass black hole candidates. The temperature of the disk is 10keV. In accretion flows around a supermassive black hole, the temperature of this state is 0.1-1keV, and may correspond to the warm Compton region in active galactic nuclei.

We present the results of global three-dimensional radiation magnetohydrodynamic simulations of black hole accretion flows during the hard-to-soft state transition. We applied a radiation MHD code CANS+R, in which HLLD scheme is adopted for approximate Riemann solver. Higher order MP5 scheme is used to interpolate the cell interface values. The radiation field is computed by using the M1-closure scheme. Effects of Compton scattering are considered. We confirmed that when the accretion rate is 0.1LEdd/c2, where LEdd is the Eddington luminosity, magnetic pressure supported quasi-steady disk is formed, and co-exists with optically thin hot accretion flows near the black hole. When the Thomson optical depth of the radiatively cooled region exceeds 10, radiation pressure becomes dominant, and excites radial oscillations. When the mass of the central black hole is 107 solar mass, soft X-ray emitting warm Compton region is formed. These results can explain the soft X-ray excess and rapid time variabilities observed in changing look active galactic nuclei. We discuss the possibility of the formation of relativistic jets when the magnetic flux accumulated in the magnetically supported disk is released.

KEYWORDS accretion disk, black hole, radiation MHD, jets, x-ray astronomy, AGN, numerical simulation

FM 1

#3398

Radio Broadband Spectro-polarimetric Time Variabilities of AGN Jets

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Radio broadband spectro-polarimetric observations have been shown to be a powerful probe of the magnetic field in AGN jets, as well as the embedded and the ambient thermal plasma. This is because of the ability of the Faraday tomography technique in identifying multiple polarisation components that are spatially blended with one another, in addition to the vastly improved sensitivity. Furthermore, the study of time variabilities of these sources, in both total intensity and polarisation, are invaluable to our understanding of the jet structures. Yet, this has not been explored in details. We have used the Karl G. Jansky Very Large Array (VLA) to observe a sample of 23 AGNs in both 2014 and 2017 across 1-2 GHz. The highly sensitive broadband spectro-polarimetric data have revealed clear time variabilities in polarisation for about one-third of our sample across the 3-year timespan: in polarisation fraction, intrinsic polarisation angle, and/or rotation measure. In this poster, we will present the results and discuss the implications, as well as highlighting potential pitfalls for similar experiments in the future.

KEYWORDS

FM 1

#3141

High-energy polarization - a window about to open

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High-energy polarimetry will open up a new window and play a crucial role in exploring the extreme physics of high-energy radiation, neutrino production, and cosmic ray acceleration in AGN jets. I will present the scientific potential of high-energy polarimetry and the wealth of information expected from the synergy of multi-wavelength polarimetry that will be brought to multi-messenger astronomy.

KEYWORDS polarization, gamma-rays, X-rays, AGN

1 Year of High-cadence VLBI Monitoring of BL Lacertae During its Recent γ-ray Flaring Activity

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BL Lac is a blazar at redshift z = 0.0686, and the origin of the class of so called "BL Lac type objects". Starting in Fall of 2020, BL Lac displayed a year-long period of multi-wavelength activity from radio to γ-rays. During this time, BL Lac was observed with historically bright optical magnitudes, and went through multiple x-ray and γ-ray flares. Triggered by a γ-ray flare in 2022 January, we conducted DDT observations of BL Lac at the VLBA. We monitored BL Lac using short, phase-referenced observations at 23 GHz, with the goal of investigating the absolute kinematics of different radio structures at mas scales during this historically active period. Here, we present preliminary results of our ToO observations.

KEYWORDS galaxies: active, BL Lacertae objects, galaxies: jets, VLBI, Phase Referencing

FM 1
#3190

Gamma-Ray Burst Pulse Morphologies and Time-Reversibility

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The temporal ordering of emission in gamma-ray burst (GRB) light curves provides information related to jet kinematics. A study of over 400 long and short BATSE GRB pulses finds that 86% of GRB pulses can be fitted by a light curve model combining a time-reversible smooth component with a time-reversible structured component. The stretching/compression needed to align the time-reversed smooth and structured components accurately identifies and predicts GRB pulse morphology. Asymmetric time-reversible morphological pulse types are “fast rise exponential decay pulses” (FREDs), “rollercoaster pulses,” and “asymmetric u-pulses,” while symmetric time-reversible pulse types are “u-pulses” and “crowns.” The stretching/compression characteristics of asymmetric pulses are sufficiently different from those of symmetric pulses to suggest that they might belong to separate populations. The limited range of GRB pulse morphological types provides an additional constraint on how the kinematics of ultra-relativistic jet outflow might produce time-reversible emission structures.

KEYWORDS Gamma-ray bursts, Light curve classification, Astrostatistics techniques

FM 1

#2956

Accelerated proton produced by magnetic Penrose process in Sgr A*

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Typical mechanisms to extract high-energy particles near a rotating black hole are Blandford-Znajek process and Penrose process. Penrose process requires a special condition that is difficult to occur in common astrophysical situations, however, magnetic Penrose process (MPP) does not require such special condition and can produce the ultra-high energy cosmic rays. When neutrons decays near a rotating black hole, the MPP efficiency of the produced proton is maximized. The supermassive black hole in Sagittarius A* (Sgr A*) is likely to have advection dominated accretion flow that is hot enough to produce neutrons by nuclear reactions which can be accelerated to a high energy by MPP. We estimate proton emissivity from Sgr A* via MPP and the proton flux at the Earth.

KEYWORDS Magnetic Penrose process, Cosmic ray, Black hole, Sgr A*

FM 1

#1597

Neutron-driven cosmic rays from microquasar jets

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Supernova remnants are currently believed to be the main sources from which Galactic cosmic rays originate. This scenario, however, fails to explain some of the features in the observed cosmic-ray spectrum, such as the spectral index or the breaks (i.e. knee and ankle). Microquasars have been proposed as alternative candidates, because their non-thermal emission indicates the existence of efficient particle acceleration mechanisms in their jets. Some jets, such as that of SS 433, have been observed to have hadronic content. In these cases, the production of neutrons is an inescapable consequence of hadronic interactions. Given that neutrons can not be magnetically confined, they escape from the jet and then decay, providing a way for charged particles to escape the system becoming cosmic rays. In this talk I will discuss neutron-driven cosmic-ray production in microquasar jets. I will show that this mechanism renders the most collimated, luminous, and compact microquasar jets as serious candidates for alternative cosmic-ray sources. These jets provide a non-negligible proton cosmic-ray power, with a spectrum capable of producing the features observed at energies below the knee. I will also discuss the contribution of this mechanism to Galactic and extragalactic cosmic-ray production, especially at the Cosmic Dawn, when they may have had an important role regarding the heating and reionization of the intergalactic medium.

KEYWORDS cosmic rays, ISM: jets and outflows, relativistic processes

Interferometric monitoring of gamma-ray bright AGNs: Measuring the magnetic field strength of 4C +29.45

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We present the results of multi-epoch, multifrequency monitoring of blazar 4C +29.45, which was regularly monitored as part of the Interferometric Monitoring of GAmma-ray Bright Active Galactic Nuclei (iMOGABA) program – a key science program of the Korean Very long baseline interferometry Network (KVN).

Observations were conducted simultaneously at 22, 43, 86, and 129 GHz over the 4 years from 5 December 2012 to 28 December 2016. We also used additional data from the 15 GHz Owens Valley Radio Observatory (OVRO) monitoring program.

From the 15 GHz light curve, we estimated the variability timescales of the source during several radio flux enhancements. We found that the source experienced six radio flux enhancements with variability timescales of 9–187 days during the observing period, yielding corresponding variability Doppler factors of 9–27. From the simultaneous multifrequency KVN observations, we were able to obtain accurate radio spectra of the source and hence to more precisely measure the turnover frequencies of synchrotron self-absorption (SSA) emission with a mean value of 28.9 GHz. Using jet geometry assumptions, we estimated the size of the emitting region at the turnover frequency. We found that the equipartition magnetic field strength is up to two orders of magnitude higher than the SSA magnetic field strength (0.001–0.1 G). This is consistent with the source being particle dominated. We performed a careful analysis of the systematic errors related to the making of these estimations.

From the results, we concluded that the equipartition region is located upstream from the SSA region.

KEYWORDS AGN, BLLac, Radio astronomy, KVN

FM 1

#2303

Relativistic beaming models are incongruent with large bends or misalignments seen in AGN jets

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Radio maps of AGNs often show linear features, called jets, both on pc as well as kpc scales. These jets supposedly possess relativistic motion and are oriented close to the line of sight of the observer and accordingly the relativistic Doppler beaming makes them look much brighter than they really are in their respective rest-frames. The flux boosting due to the relativistic beaming is a very sensitive factor of the jet orientation angle, as seen by the observer. However, these jets often show bends, wiggles or misalignments on different scales. The bends or misalignments seen sometimes are 90° or more that should cause a large change in the relativistic beaming factor. But the bends, wiggles or misalignments do not show such high contrasts. The question arises whether the appearances of such bends is really consistent with the jets being relativistically beamed or is there something amiss in our understanding? The usual explanation given is that it may all be due to projection effects where small changes in angle in the intrinsic frame might appear much larger, especially when seen close to the line of sight. After taking into account various projection effects in the jet appearance, we show that the relativistic beaming models along with the observed large misalignments seen in the jets of active galactic nuclei, predict large contrasts in the brightness observed before and after the misalignments, which in general, are not seen. Accordingly, the relativistic beaming models therefore are not compatible with the observed misalignments, and except in rather contrived scenarios, the observed large misalignments and their observed brightness before and after the misalignments, cannot be explained in the conventional relativistic beaming hypothesis.

KEYWORDS Active galaxies, quasars, relativistic jets, Relativistic Dopplar beaming

A comparison of approximate non-linear Riemann solvers for Relativistic MHD

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We compare a particular selection of approximate solutions of the Riemann problem in the context of ideal relativistic magnetohydrodynamics. In particular, we focus on Riemann solvers not requiring a full eigenvector structure. Such solvers recover the solution of the Riemann problem by solving a simplified or reduced set of jump conditions, whose level of complexity depends on the intermediate modes that are included. Five different approaches – namely the HLL, HLLC, HLLD, HLLEM, and GFORCE schemes – are compared in terms of accuracy and robustness against one – and multidimensional standard numerical benchmarks. Our results demonstrate that – for weak or moderate magnetizations – the HLLD Riemann solver yields the most accurate results, followed by HLLC solver(s). The GFORCE approach provides a valid alternative to the HLL solver being less dissipative and equally robust for strongly magnetized environments. Finally, our tests show that the HLLEM Riemann solver is not cost-effective in improving the accuracy of the solution and reducing the numerical dissipation.

KEYWORDS MHD, Relativity, Riemann Solvers, Numerical Methods, shock waves

FM 1

#2216

Identification of a new S-shaped giant radio galaxy

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Distorted giant radio galaxies (GRGs) are one of the most exciting objects. However, there are very few S-shaped GRGs discovered till now. The orientation of the jet is connected to the spin of the central supermassive black hole. Theory suggests there may be a pair of supermassive black holes orbiting each other or a tilted massive accretion disc present at the centre of those galaxies, which is the primary reason behind the slow change of the spin axis. While searching for simple GRGs, we found an interesting case of an S-shaped GRG. We have already obtained the low-frequency observations of this target. The source has no sign of backflow or recurrent activity. Therefore, this GRG is suitable for addressing the intriguing issue of S-shaped radio galaxies.

KEYWORDS

FM 1

#2220

Are giants the ancient radio galaxies?

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The reason for which giant radio galaxies (GRGs) can achieve very large lengths is not yet fully apparent. The sizes of GRGs depend mainly on three factors, i.e., IGM density, jet power, and age of the sources. Therefore, we decided to carefully investigate one of the largest and the brightest GRGs since it is likely that all significant favourable growth factors are present in this system. Furthermore, we aim to perform an ageing analysis of this GRG. Using multiwavelength dedicated and archival radio observations, we determined the synchrotron and dynamical age of the lobes. In addition, we obtained several other physical parameters of this object, which we are currently exploring.

KEYWORDS

FM 1

#2176

Relativistic Outflows from a GR-MHD Mean-field Disk Dynamo

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We will present resistive GR-MHD simulations of thin accretion disks around black holes, including a mean-field disk dynamo.

The dynamo produces a large-scale magnetic flux from a weak seed field in an initially thin disk.

A standard, non-local quenching mechanism is applied to mitigate an otherwise exponential increase in the magnetic field.

The dynamo-generated magnetic flux expands from the disk interior into the disk corona, becomes advected by disk accretion, and fills the axial region of the domain.

The dynamo leads to an initially rapid increase in magnetic energy and flux, while for later evolutionary stages the growth stabilizes.

Accretion toward the black hole depends strongly on the type of magnetic-field structure that develops.

The radial field component supports extraction of angular momentum, and thus accretion.

It also sets the conditions for launching a disk wind, initially from the inner disk area.

Strong winds can be launched, predominantly driven by the pressure gradient of the toroidal field.

For spinning black holes, we identify a Poynting flux-dominated jet, driven by the Blandford-Znajek mechanism.

This axial Poynting flux is advected from the disk, and therefore accumulates at the expense of the flux carried by the disk wind, which is itself regenerated by the disk dynamo.

KEYWORDS MHD, Black Holes, Jets, Outflow, Dynamo, General Relativity

FM 1

#2149

Correlation (or not) between the Spin Directions of Supermassive Black Holes and their Host Galaxies

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The existence of varioius correlations between properties of supermassive black holes (SMBHs) and their host galaxies has implied critical roles SMBHs play in the formation and evolution of massive galaxies. In this work, we attempt to examine whether there is any correlation between the spin directions of SMBHs and their host galaxies. Using the final galaxy from SDSS-IV MaNGA survey, we have assembled a sample of 130 galaxies with prominent jets, which enable us to infer the (projected) spin direction of their SMBHs. The kinematics of the galaxies are measured from MaNGA stellar velocity maps. We have developed an analytic framework that enables us to infer the correlation of the spin directions in 3D, given the ensemble distribution of the 2D, observed angle differences of the jet and galaxy kinematic position angles. Considering the huge difference in the scales, a naive expectation is a null detection of any correlation. Surprisingly, we have found that, for elliptical galaxies with younger ages (lower values of 4000 angstrom break), there exists strong correlations, particularly for those with lower velocity dispersion. A possible explanation of the correlation is that mergers that create lower mass, young elliptical galaxies, which presumably are wet mergers involving disk galaxies, likely retain the "memory" of the spin alignment of the progenitors.

KEYWORDS radio galaxies, jets, galaxy kinematics, galaxy formation

FM 1
#1640

The X-ray property of the forward shock in magnethydrodynamic simulations of active galactic nucleus jets

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It is widely accepted that radio-mode feedback plays a fundamental role in the formation and evolution of galaxies and large-scale structures. Some radio jets drive forward shocks into the intracluster medium, and these shocks are observed as X-ray surface brightness discontinuity. The property of forward shocks gives an important clue to understanding the energy budget of radio-mode feedback and the nature of the tenuous plasma. Some hydrodynamical models for powerful jets successfully reproduce observed structures. However, there is a discrepancy between the simulations and observations. Namely, the observed Mach number of the forward shock is much lower than one from the situation.

In this work, we performed a synthetic X-ray observation of powerful radio jets in a galaxy cluster, using the data of two-temperature magnetohydrodynamic simulations, to investigate the projection and temperature non-equilibration effects in a measurement of Mach number. We find that the measured Mach numbers from the X-ray surface brightness profile strongly depend on inclination angle. At a high inclination angle, we estimate the Mach number of 6, which is consistent with our model. Meanwhile, the measured Mach number is lower than 2 at a low inclination angle. We also estimate post and pre-shock spectroscopic-like temperatures. The projection effect significantly reduces the temperature jump for any inclination angle. As one of the examples, we compare our results with the results of Cygnus A. As a result, our models suggest that the inclination angle of Cygnus A should be less than 50 degrees. The observed temperature jump of our two-temperature model is also consistent with that of Cygnus A. Finally, our main conclusion is that we should be careful to estimate and discuss the jet kinetic power from the Mach number of the forward shock.

KEYWORDS Jets, shock, cluster, X-ray

FM 1
#1549

EAVN study of Sgr A* during flaring Activity of 2019

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The supermassive black hole (SMBH) in our Galactic Center, Sagittarius A* (Sgr A *), is the closest known SMBH with a mass of $M_{BH} \sim 4 \times 10^6 M_\odot$ at a distance of D ~ 8.1 kpc. Thanks to its proximity, Sgr A* subtends the largest angle size in the sky among all known black holes and is one of the most promising targets to study the vicinity of a black hole through direct imaging. At present, the observations and theoretical models converge on the fact that the mm/sub-mm radiation is emitted from a region within several Schwarzschild radius (R_s) of the black hole. This region is thought to be the jet base of Sgr A* or a radiatively inefficient accretion flow (RIAF) or a combination of both. However, the southern declination and interstellar scattering towards Sgr A* add challenges to decades of radio observations with very long baseline interferometry (VLBI). Thus, the intrinsic accretion and outflow structure of Sgr A* remains rather poorly understood. Sgr A* shows variability from minutes to months timescale at a variety of wavelengths. The source exhibits frequent flares at near-infrared (NIR) and X-rays which may be attributed to an expanding blob within an outflow or rotating hot spots around the central SMBH.

Remarkably, it has been reported that Sgr A* became brighter at NIR in 2019 May than ever measured at this wavelength before, which may be attributed to a delayed enhancement of accretion from either the G2 encounter in 2014 or the recent passage of the S0-2 star in 2018. Through our long-term EAVN monitoring, we have also found flux enhancements in 2019, the highest flux (~ 2.1 Jy) has been detected in Sgr A* in 2019 May which may indicate increased activity of Sgr A*.

KEYWORDS , Galactic Center, Supermassive black holes, Very long baseline interferometry, Accretion

FM 1

#1047

Jets from gamma-ray bursts: A detailed view of GRB 171205A

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The jets associated to gamma-ray burst (GRB) are produced during the collapse of a massive star, and include material expelled at ultra-relativistic velocities. The GRB itself is produced by internal shocks within the jet and when the ejecta collides with the interstellar medium, it produces an afterglow that is observable at all wavelengths. By studying its broadband evolution we can gain insight about the micro- and macro-physics involved in the explosion.

Here I will review the multi-wavength observations of GRBs as a context for the observations of GRB 171205A, which has one of the best multi-wavelength datasets recorded to date. Our data ranges from 400 MHz to X-rays and extends for over 4 years. Early optical data showed a cocoon emission associated with the jet. When observed in a wider wavelength range, the emission is even more complex AND multiple components are needed to explain its evolution.

KEYWORDS Jets, GRBs, Multi-wavelength

FM 1
#997

Far-infrared study of particle acceleration in hot spots of FR-II radio galaxies

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Far-infrared emission in the wavelength range of 100-500 micron has been discovered with the Herschel observatory from two prototypal jet-terminal hot spots, i.e., hot spot D in the FR-II radio galaxy Cygnus A and the west hot spot of Pictor A. The far-infrared spectrum of hot spot D in Cygnus A is found to be smoothly connected to the radio one. Thus, the far-infrared emission from this object is interpreted as the high-frequency end of the radio synchrotron emission. By closely analyzing the multi-wavelength spectrum, a break feature is detected at the frequency of 2.0+1.2–0.8 THz with an energy index change of 0.5. This break is naturally ascribed to the cooling break which is expected in the diffusive shock acceleration under a continuous energy injection condition. From the derived cooling break frequency, the magnetic field strength in this hot spot is tightly constrained as B = 120 - 150 micro Gauss. In contrast, the far-infrared flux from the Pictor A west hot spot exhibits a significant excess over the power-law extrapolation from the radio spectrum. This excess is found to have a notable contribution up to the mid-infrared band around the wavelength of 10 micron. In order to reproduce this spectral excess, a broken power-law component, with the break frequency of 1.6+3.0-1.0 THz, subjected to a high-energy cutoff is required. Importantly, the spectrum below the break (the energy index of 0.22) is significantly harder than that predicted in the strong shock limit (the energy index of 0.5). A stochastic acceleration via plasma turbulence, which is operated in 10-pc scale substructures resolved with a high-resolution radio interferometric image within this hot spot, is invoked to explain the far-infrared excess from the west hot spot of Pictor A. These results indicate that the far-infrared data are useful to investigate whether the standard diffusive shock acceleration is simply applicable (Cygnus A hot spot D) or not (the Pictor A west hot spot).

KEYWORDS Galaxy jets, Non-thermal radiation, Radio hot spots, particle acceleration, far-infrared astronomy, Fanaroff-Riley radio galaxies, magnetic field

FM 1

#946

Early-time colour variations in the GRB 201015A afterglow

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Instruments such as the ROTSE, TORTORA, Pi of the Sky, MASTER-net, and others have recorded single-band optical flux measurements starting as early as ~ 10 s after the gamma-ray trigger. The earliest measurements of optical spectral shape have been made only much later, on hour time scales, never on the time scale approaching a few minutes or less, until now. We began observations of GRB201015A beginning only 58 seconds after the Swift BAT trigger, measuring simultaneously in three filter bands, g', r', and i', using the Burst Simultaneous Three-Channel Imager (BSTI, see Grossan & Maksut 2020) instrument on the Nazarbayev University Transient Telescope at Assy-Turgen Astrophysical Observatory (NUTTelA-TAO). We observed the afterglow peak and a power law temporal decay, t^−α , with α1 =1.2±0.07 bewteen 500 and 1600 seconds, but later this changed to a value of α2=0.8±0.1 between 1900 and 4000 seconds. The spectrum between the three filters was consistent with a power law f_ν ∝ ν^−β with a value of β of 0.73±0.08 at the peak, 130 to 500 seconds, and 0.42±0.14 during the "early afterglow" phase, 500 to 1600 seconds, and 0.01±0.11 during the later afterglow phase, 1900 to 4000 seconds (we assumed a galactic reddening of 1.12, 0.77 and 0.58 mags, and source reddening of 0.19, 0.14 and 0.11 mags for the sloan g', r' and i' filters, respectively). We measured the X-ray temporal decay index of 0.8 ±0.1 which is consistent with our late optical temporal decay index and Chandra X-ray decay index reported by Gompertz et al. (2020). Changes from one power law decay time and spectral index to another in this phase of the afterglow have been attributed to jet components of different angular extent dominating emission at different times (e.g. Racusin et al. 2008), or the transition from reverse shock emission dominance to forward shock dominance (e.g. Vestrand et al. 2014, Racusin et al. 2008, Wozniak et al. 2009, Bloom et al. 2009); we discuss the relative merits of these scenarios in the body of this work. The changes we see in spectral shape in early afterglows suggest that significant information about this emission phase (and possibly prompt emission, if observed early enough) is being missed without such fast (sub-minute) response observations with simultaneous multi-color instruments.

KEYWORDS gamma-ray burst, individual: GRB 201015A, relativistic jets, emission mechanisms

FM 1
#685

Correlations of the multiwavelength emission in the blazar CTA 102 during 2016-2018

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Blazars are among the most powerful objects in the universe. Their relativistic jets pointing towards Earth show variable flux density across the entire electromagnetic spectrum. The Fermi-Large Area Telescope observed the active gamma-ray states in the blazar CTA 102 from 2016 to 2018. During this period, we find two prominent gamma-ray outbursts called flares. In this study, we investigate correlations of the multiwavelength emission to figure out the nature of the gamma-ray flares. The multiwavelength light curves from radio to X-ray energies show flares that seem to be associated with the gamma-ray flares. We employ the cross-correlation function and find a $> 2\sigma$ correlation between the radio and gamma-ray energies. The optical/X-ray emissions show $> 3\sigma$ correlations with the gamma-ray emission. Moreover, we use the 43 GHz Very Long Baseline Array (VLBA) data to explore the kinematics and flux variability in the parsec-scale jet of this source during the 2018 gamma-ray flare. This gamma-ray flare is associated with an ejection of a jet component from the radio core. Based on the results of the cross-correlation analysis and the jet kinematics, we suggest the origins of the gamma-ray flares.

KEYWORDS Jets, Blazar, CTA 102, Gamma-rays, Radio continuum, VLBI

FM 1

#643

Particle acceleration at relativistic jets of FR-II radio galaxies

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Relativistic jets from radio galaxies are promising candidates for sources of ultra-high energy cosmic rays (UHECRs). To study the acceleration of UHECRs at relativistic jets, we first performed 3D relativistic hydrodynamics (RHD) simulations of relativistic jets with a newly developed RHD code based on the high-accurate weighted essentially non-oscillatory (WENO) scheme, focusing on high-power FR-II radio galaxy jets. Nonlinear flow structures, such as shock, turbulence, and shear, which should be directly linked to particle acceleration, were examined in detail. We then followed and analyzed the acceleration of particles in simulated jets of a few hundred kpc scales through Monte-Carlo particle transport simulations. We found that the shear acceleration is the most important process in the energization of UHECRs, while the diffusive shock acceleration and the turbulent acceleration also play non-negligible roles. The energy spectrum of accelerated UHECRs is hard with dN/dE ~ E^{-0.8}- E^{-0.4}, as the shear acceleration is dominant at the highest energies, depending on the scattering law. We also developed the modeling of UHECR observations at Auger and TA, based on the UHECR spectrum we obtained. In this talk, we present the results of this work.

KEYWORDS galaxies: Jets, galaxies: Active, accelertaion of particles, cosmic rays, relativistic hydrodynamics, method: numerical

FM 1

#501

Correlation study between X-rays and TeV gamma-rays on blazars

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The spectral energy distribution (SED) of blazars is formed by two radiative components, which are commonly modeled within the standard one-zone synchrotron self-Compton (SSC) leptonic scheme. In this model, it is expected a strong correlation between energy bands fluxes of the SED components, such as between the X-ray and TeV gamma-ray fluxes. The correlations obtained before are often reported in small periods and are not clearly consistent among them, so to know if there is a unique correlation behavior, a long period study is required. Here we search and study the long-time correlation of 4 BL Lac, HBL sources at $z<0.1$. We find that only one of them prefers a linear correlation as the result obtained for Mrk 421 by Gonzalez et al, (2019). The other three blazars show a correlation described as a power-law with power indexes between 1.25 +/- 0.22 and 1.45 +/- 0.09. Among the results, we found disagreements between what is reported in previous works. E.g., two-zoned jets produce non-linear correlations and it is expected a linear correlation when the TeV gamma-rays are produced in the Klein-Nishina regime.

KEYWORDS Blazars, Multiwavelength correlations, Jet emission mechanism, gamma-ray emission, X-ray emission

FM 1

#425

Black Hole Spins from Relativistic Reflection Modeling of Accretion Disks in Radio-quiet AGN

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The general-relativistic strong gravity of a spinning supermassive black hole (SMBH) geometrically influences the surrounding inner accretion disk, whose reflected X-ray spectra can be used to probe the black hole spin. In this work, we consider a sample of radio-quiet active galactic nuclei (AGN) with low line-of-sight inclinations suitable for studying the inner accretion disk owing to less dust obstruction. The black hole spins are then determined through a sophisticated Markov chain Monte Carlo (MCMC) analysis of a relativistic ray-tracing reflection model fitted to the relativistically broadened K-alpha iron line and Compton hump, which allows us to put statistical constraints on the best-fitting spin parameter, inclination angle, and reflection fraction. SMBH spins can help us get a better picture of how near-relativistic ultra-fast outflows are launched in AGN.

KEYWORDS Black Hole Spins, Active Galactic Nuclei, Reflection Modeling, Supermassive Black Holes, Radio-quiet AGN, Ultra-fast Outflows, Relativistic Jets

FM 1

#408

Cosmic evolution of the jetted AGN population

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It was recently found that the cosmological evolution of the jetted AGN population significantly differs when observed in the X-ray or the radio band. Their X-ray space density peaks at much earlier times (z~4) when compared to their radio one (z~2), which would imply a different redshift evolution of the typical X-ray luminosities with respect to the radio ones. We show how this different evolution can be explained by the increase of the X-ray emission in jetted AGNs, due to the Inverse Compton interaction between the CMB photons and the electrons within relativistic jets (IC/CMB). Indeed, at high redshift we expect this type of mechanism to dominate the high-energy emission at scales larger than a few kilo-parsec. Our results are based on statistical studies and simulations performed on the largest well-defined samples available to date (up to z~5). Moreover, this scenario is also supported by the detailed study of the most distant jet resolved to date (z=6.1) both in the X-ray and in the radio band.

KEYWORDS AGN, X-ray, high-z, evolution, blazar

e-Talks

FM 1

#3014

Future Prospects for Constraining Black Hole Spacetime: Horizon-scale Variability of Astrophysical Jet

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The Event Horizon Telescope (EHT) has ushered in a new era for observing the strong gravitational field and testing general relativity. Recent observations of the horizon scale images of the supermassive black hole M87* at the nearby galaxy M87 provide direct information in the vicinity of the black hole. The comparisons of the EHT observations and theoretical simulations enable us to constrain the spacetime, while it is not easy to decompose into the accretion flow properties and spacetime information because the radiation complexly depends on their effects. The next generation EHT (ngEHT) projects are expected to explore the astrophysical jet dynamics around the black hole, one of the most promising topics for extracting spacetime information.

We demonstrate that the black hole spacetime can be constrained by focusing on the dynamics of the jet under the observational environments of ngEHT projects. We utilize the three-dimensional general relativistic magnetohydrodynamic (GRMHD) simulation of magnetically arrested disks (MADs) with the numerical code BHAC. The simulated jet movies are calculated with the general-relativistic radiative transfer (GRRT) scheme of the numerical code BHOSS. Around the jet base, the launched jet has intermittent wave structures, which propagate with a relativistic time scale. The wave velocity and time development can be extracted from the simulated movies and show monotonic dependence on the black hole spacetime. We finally perform the synthetic observation of M87* and show the detectability of velocity features and the black hole spacetime information under the expected ngEHT observations.

KEYWORDS Accretion, Black hole physics, Gravitation, Radiative transfer, magnetohydrodynamics (MHD), Galaxies: individual: M87

Resolving the acceleration and collimation zone in a jet of flat spectrum radio quasar, 1928+738

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We investigated the jets in the nearby flat spectrum radio quasar (FSRQs) 1928+738 (a.k.a 4C +73.18). The 1928+738 jet is mostly misaligned (13 degree) from line of sight among FSRQs. It makes an excellent target for investigating the acceleration and collimation zone of FSRQ, which is not extensively studied yet. We explored the structural evolution and the kinematics of the jet, using various archival and our own VLBI observations. The multi-frequency observations made it possible to analyze the jet across a wide distance range, from <1 to 40 million gravitational radii. Interestingly, we find that the jet is actively collimated and accelerated continuously out to a distance of ~6 million gravitational radii, suggesting a coexistence of the jet acceleration and collimation zone (ACZ). It is similar to the observational results of the two nearby radio galaxies (M87 and NGC 315) and a narrow line Seyfart galaxy 1H 0323+342. We remark that 1928+738 is the fourth radio-loud AGN and the first FSRQ, for which the ACZ is firmly discovered. In this talk, we will present the overall observational results of 1928+738 jet.

KEYWORDS jet, AGN, quasar, acceleration, collimation, SMBH, VLBI

FM 1
#2377

Orientation of jet axes with observer's line of sight and the discrepancies seen with the unified scheme of powerful radio galaxies and quasars

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Relativistic jets are believed to be collimated channels through which energy gets supplied to distant lobes in powerful radio galaxies. The orientation of the observer's line of sight with respect to the jet axis results in large changes in the appearance of the radio source to the observer, supposedly because of an opaque dusty torus surrounding the inner core. In the unified scheme if the observer's line of sight falls within the opening angle of the torus and the observer thereby can see the inner parts of the source, the radio source may appear as a radio loud quasar, otherwise it will appear as a radio galaxy. Accordingly, depending upon the opening angle of the torus, believed to be ~45°, relative numbers and sizes of quasars should appear smaller than those of radio galaxies, when tested against redshift, flux-density, luminosity or even angular distribution in sky. In the 3CRR sample itself, based on which the unified scheme was proposed in the first place, the number and size ratios of radio galaxies and quasars fluctuate in a statistically significant manner when the sky is divided in two parts, say, 00-12 hr and 12-24 hr in RA. It looks as if the orientation-based unified scheme could at most be valid in only one half (12-24 hr) of the observed sky, but is violated in the other half. Further, we show that the simple, unambiguous predictions of the unified scheme are not borne out, in almost any sample that we examined, and which had the requisite radio and optical information (3CRR, MRC, BRL). Their relative numbers, quantified by the quasar fraction in individual samples, should match their size ratios in a well-defined manner, even if the opening angle of the torus were varying. But it does not agree with observations in any of the known complete samples we examined. These results unambiguously indicate that there is an intrinsic difference in the size distributions of quasars and radio galaxies, and the unified scheme, where the differences in the observed sizes of radio galaxies and quasars are attributed to geometric projection effects, supposedly arising from different orientations of observer's lines of sight with respect to the jet axes, can be rejected at a statistically high significant level.

KEYWORDS Active galaxies, quasars, Relativistic jets, Unified scheme of AGNs

FM 1

#2218

Constraining jets from gravitational wave mergers with VLBI: challenges and opportunities

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Short gamma-ray bursts (SGRBs) offer an opportunity to study extreme examples of transient jets, providing insight into both the jet physics and the merger progenitors. While SGRBs have traditionally been seen only on-axis and at typically high redshift, the advent of gravitational-wave merger (GWM) detections means that much closer, off-axis events can also be identified and studied. The prototypical example of this new category was the landmark detection of the multiwavelength counterpart to binary neutron star merger GW170817, which provided an unprecedented view of an SGRB. In particular, its relative proximity enabled very long baseline interferometric (VLBI) observations that identified superluminal proper motion of the merger's relativistic outlow, breaking the degeneracy between competing afterglow models and setting much tighter constraints on key jet parameters. However, VLBI data typically includes systematic sources of uncertainty that can be difficult to quantify, and will often be of low signal-to-noise for typical GWM jets. These two challenges complicate the estimation of jet parameters and especially the associated uncertainty. In this talk, I will discuss the main model-fitting challenges we face and present possible solutions toward more robust results.

KEYWORDS SGRB, gravitational waves, VLBI, neutron star mergers, jets, model-fitting

FM 1

#2114

Structure and Variability of Magnetically Dominated Jets from Accreting Black Holes

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Energy extraction from the rotating black holes is a viable mechanism for explaining the power of relativistic jets, observed from stellar mass to the supermassive black hole scale. In Gamma Ray Bursts, the structured jets have recently been invoked to explain their complex emission. In particular, the source GW170817 is an example of a structured jet, observed off-axis and interacting with the post-merger ejecta and accretion disk wind.

Observational studies have also shown an anticorrelation between the jet variability, measured by its minimum timescale, and the Lorentz factor. The correlation spans several orders of magnitude, from blazars to GRBs scales. Finally, power density spectral slopes of GRBs variability seem to be correlated with their peak energies.

The variability of a jet manifested on different timescales may be driven by central engine instabilities, imposed by strong magnetic fields in a magnetically arrested state, and by the jet interactions with its environment.

I will present recent developments of the jet and central engine models, with particular focus on the results of numerical GR MHD simulations. I will also present observational constraints for these models.

KEYWORDS jets, gamma ray bursts, MHD, variability

FM 1
#2001

Circumnuclear multi-phase gas around the central AGN in a cool-core cluster, A1644-South

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We present the active galactic nucleus (AGN) jet and the circumnuclear multi-phase gas properties of the brightest cluster galaxy (BCG) in the center of Abell 1644-South (A1644-S). The primary goal is to investigate how the large-scale cluster cooling environment ultimately affects small-scale AGN activity at the cluster center. The sharply peaked X-ray surface brightness profile of A1644-S implies the presence of a cooling gas flow. Also, its prototypical X-ray hot gas sloshing indicates that A1644-S is in a merging system where intracluster medium (ICM) cooling has recently started. In order to probe how the flow of cooling gas fuels the central supermassive black hole and leads the AGN activities in the early stage of a cool-core cluster, we analyze the ALMA CO and CN (1-0) data, JVLA HI data, and KaVA 22 GHz data for the central region of A1644-S. Based on the spatially resolved morphology and kinematics of CO gas, we suggest a connection between the cold molecules and the hot ICM cooling. HI and CN gas is detected in absorption with an extended redshift tail, suggesting the cool gas is falling to the nucleus and then fed to the central AGN. Indeed, we find a parsec-scale bipolar jet at 22 GHz in the center of A1644-S, which implies that this AGN has been (re)triggered quite recently. Combining this, we discuss the role of circumnuclear cool gas in fueling the centrally located cluster AGN in the cool-core environment.

KEYWORDS Galaxy cluster, cD galaxy, ISM, AGN jet, Interferometry

FM 1
#1941

Shock-ionized bubbles powered by super-critical accretion

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Do black holes and/or neutron stars in the super-critical accretion regime have relativistic jets? Or broader, semi-relativistic winds? What is the kinetic power of such outflows? I discuss the evidence available from the multiband study of stellar-mass super-critical accretors in the local universe (some of them classified as ultraluminous X-ray sources). Large (~100-pc-scale) shock-ionized nebulae around some of those sources are an excellent indicator of strong mechanical power: I review recent studies and present new results. Understanding the role of mechanical power in the super-critical regime for stellar-mass black holes also provides important clues for the modelling of quasar feedback in their super-Eddington growth phases.

KEYWORDS ULXs, fast shocks, accretion physics, X-rays

Probing the multiwavelength emission scenario of GRB 190114C

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The multiwavelength observation of GRB 190114C, one of the extremely bright gamma-ray bursts (GRBs), opens a new window for studying the emission mechanism of GRBs. The Very-High-Energy (VHE; >100 GeV) detection by MAGIC suggested the inverse Compton process as the emission mechanism for the VHE gamma-rays during the early afterglow phase of the burst. However, other VHE GRB detections have casted doubt on this scenario as the inverse-Compton emission has not been clearly observed in other bursts. Furthermore, in GRB190114C, only a limited number of statistical and systematic studies on the emission scenario have been performed. Here, we perform the full likelihood analysis with the multiwavelength dataset: Swift-XRT, Swift-BAT, Fermi-GBM, Fermi-LAT, and MAGIC. We compute the statistical preference of the combined synchrotron (syn) and synchrotron self-Compton (SSC) model over the syn-only model, and check the stability of this preference.

KEYWORDS Gamma-ray bursts, Inverse Compton, Emission scenario, multiwavelength, GRB190114C

FM 1
#1486

MIGHTEE: revealing the radio properties of J0224.2-0528, a giant radio galaxy in the XMM-LSS Early Science field

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We report the radio properties of a giant radio galaxy (GRG) J022413.9-052819, hereafter referred to as J0224-0528. We have mainly used data at 1.4 GHz from the MeerKAT International GHz Tiered Extragalactic Exploration (MIGHTEE) Early Science survey. J0224-0528 lies in in the XMM Large Scale Structure (XMM-LSS) field and is associated with an optical host galaxy located at a redshift of z ~ 0.77. Reported as among the 20 largest sources in previous Giant Meterwave Radio Telescope (GMRT) observations, it has a projected linear size falling between the range of 0.8 – 1.1 Mpc and a radio power of 4.6*10^26 WHz^-1. Its morphology is characterized by two elongated edge-brightened radio emission with a low core prominence of ~10^-4. We derive the spectral index for all pixels with fluxes of the above 3σ in both the 150 MHz LOFAR and the 1.4 GHz MIGHTEE and we found a spectral index of ~ -1 at central region and flat index up to ~ -0.5 in the lobes. Therefore we conclude that J0224-0528 is either an active FRII but with a buried core or an FRII which core has recently switched off.

KEYWORDS galaxy, radio continuum, active, giant radio galaxy, individual, J0224.2-0528

FM 1
#1425

Should we connect the dots? Probing EVPA rotations in Blazar polarimetric time-series with Gaussian Processes

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The study of electric-vector position angle (EVPA) time-series in blazars currently lacks a sound statistical approach. This can have potential astrophysical implications, and is thus sufficiently relevant to merit a detailed investigation. The ambiguity in the construction of EVPA light-curves from the time series of Stokes Parameters introduces an intrinsic information gap that cannot be directly circumvented. To allow for a univocal reconstruction of the EVPA light-curve profile, minimum step and continuity hypotheses are traditionally applied. But the applicability of such continuity hypotheses is usually not based on solid statistical grounds, and is therefore subject to some level of arbitrariness, as has been demonstrated. In particular, the fact that polarimetric light-curves are often under-sampled with respect to the typical timescales of variability of the sources means that these methodological shortcomings have a direct impact in the EVPA time profile reconstruction and the identification of rotation events. In this contribution we will describe a simple statistical test based on a Gaussian Process approach aimed at defining the intrinsic limitations of a given dataset to the reconstruction of the EVPA time-series profile. The model-free test can be directly applied to any dataset and prevents the reconstruction of EVPA profiles whenever the light-curve under sampling is such that not enough information is available to allow for the application of the continuity hypotheses between sequences of points within a dataset. We will also present the implications of this analysis to the current statistics and studies of EVPA rotations in blazars.

KEYWORDS Relativistic Jets, Blazars, Optical Polarimetry, EVPA Rotations, Astrostatistics, Gaussian Process

FM 1

#1383

Association of molecular clouds and their details at western part of W 50/SS 433

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We conducted observations and analyses of the molecular clouds, N1 to N4, identified by Yamamoto et al. (2008) at the western side of W 50/SS 433 taken with Nobeyama 45m and JCMT 15m telescopes. N4, which is located at the nearest from SS 433 and the same line of sight as the radio continuum shell at 1.4GHz, has a strong gradient of the integrated intensity of 12CO(J=1–0, 3–2) emission at the northern, eastern, and western edges. The main body of N4 has a velocity gradient of ~0.16 km s^–1 (20")^–1 from north to south. A velocity shift by up to ~3 km s^–1 from the systemic velocity at ~49 km s^–1 is detected at only the northwestern part of N4. The Calculated number density of H2 and kinetic temperature by the RADEX code for N4 is an order of 10^3 cm^-3, and kinetic temperature ranges from ~20 to ~56 K. The position of maximum kinetic temperature corresponds to that where the velocity shift by up to 3 km s^-1. The thermal and turbulent pressures in N4 are estimated to be ~10^5 K cm^–3 and ~10^7 K cm^–3, respectively. The relation of the thermal and turbulent pressures in N4 tends to be similar to that of the molecular clouds in the Galactic plane. However, these values are higher than those in the typical molecular clouds in the Galactic plane. Several pieces of circumstantial evidence representing the physical properties of N4 and comparison with the data of infrared and X-ray radiation suggest that N4 is interacting with a jet from SS 433. In order to get further evidence and detailed properties of the shock between N4 and the jet, we also conducted an observation of the ground state of OH emission. However, any OH emission/absorption is not detected toward N4. A comparison of N1 to N3 with mid/far-infrared radiation, radio continuum, and atomic hydrogen cloud indicates that the interstellar medium is compressed in front of the radio continuum radiation at 1.4 GHz by W 50/SS 433.

KEYWORDS X-ray jet, molecular clouds, SS433

Spectral Analysis of Parsec-Scale Jet in M87: Observational Constraint on the Magnetic Field Strengths in the Jet

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Because of its proximity and the large black hole size, M87 is one of the best targets for studying the launching mechanism of the AGN jets. Currently, magnetic fields are considered to be an essential factor in the launching and accelerating of the jet. However, current observational estimates of the magnetic field strength of the M87 jet are limited to the innermost part of the jet (≤ 100 rs), or HST-1 (~ 105 rs). No attempt has yet been made to measure the magnetic field strength in between. We aim to infer the magnetic field strength of the M87 jet out to a distance of several thousand rs by tracking the distance-dependent changes in the synchrotron spectrum of the jet from high-resolution VLBI observations. In order to obtain high-quality spectral index maps, quasi-simultaneous observations at 22 and 43 GHz were conducted using KVN and VERA (KaVA) and the VLBA. We compare the spectral index distributions obtained from the observations with a model and place limits on the magnetic field strengths as a function of distance. The overall spectral morphology is broadly consistent over the course of these observations. The observed synchrotron spectrum rapidly steepens from α22-43 GHz ~ -0.7 at ~ 2 mas to α22-43 GHz ~ -2.5 at ~ 6 mas. In the KaVA observations the spectral index remains unchanged until ~ 10 mas but this trend is not clear in the VLBA observations. A spectral index model in which non-thermal electron injections inside the jet is decreasing with distance can adequately reproduce the observed trend, and it suggests the magnetic field strength of the jet at a distance of 2 - 10 mas (~ 900 rs - ~ 4500 rs in de-projected distance) has a range of B = (0.3 - 1.0 G) (z/2mas)-0.73. Extrapolating to EHT scale yields consistent results, suggesting that the majority of the magnetic flux of the jet near the black hole is preserved out to ~ 4500 rs without significant dissipation.

KEYWORDS M87, relativistic jet, VLBI, multi-frequency observation, spectral analysis, magnetic field

FM 1
#900

Searching for peculiar GRBs with temporal and spectral properties outside the canonical classification

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The canonical classification of Gamma-Ray Bursts establishes short (SGRBs, < 2s) and long GRBs (LGRBs, > 2s) according to temporal and spectral properties. Combining the prompt and afterglow emissions of GRBs and host galaxies, the canonical classification seems to be not enough sufficient to identify their real nature. This is the case of GRB 200826A, discovered by the Fermi space telescope in 2020, whose duration is ~1 second. After analyzing its spectral properties, isotropic energy, host galaxy offset, afterglow, and a likely association with a supernova emission, GRB 200826A is more consistent with LGRBs despite the fact that its short duration. Thus, there would be apparently SGRBs whose real nature is maybe associated with LGRBs.

In order to identify additional peculiar GRBs that do not follow the canonical classification, we analyzed the third Swift/BAT Gamma-Ray Burst catalog, which contains information of 1391 events (452 GRBs with known redshifts) from December-2004 to May-2021. We considered parameters as the T90, the isotropic and peak energy Epeak (condensed in the Amati Relation), and the spectral lag (from the cross-correlation function) between different energy bands. We established the Amati relation for the sample (with known redshifts), where ~18 GRBs do not fall in the expected Isotropic Energy-Epeak plane according to the canonical classification. This group of GRBs represents a novel sample of events that do not follow the traditional classification and motivates to settle a new way to identify GRBs' progenitors.

KEYWORDS Gamma-Ray Bursts, canonical classification, Amati relation, spectral lag

Beaming Effect and Relativistic Jet Characteristic in Fermi Blazars

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In this talk, we will review our recent progress and important findings of the beaming effect and relativistic jet property in gamma-ray blazars detected by the Fermi-Large Area Telescope (Fermi-LAT).

Blazars are a particular class of radio-loud Active Galactic Nucleus (AGNs), characterized by many distinctive observational properties, which are due to the relativistic beaming effect. Since the beaming effect is not observable and the origin of jets is still not clear, we proposed several methods to reveal these two important issues from different perspectives, based on our derived large sample of Fermi blazars. Principally, we come to the results and conclusions as follows:

(1) We present an effective method by means of the beaming effect to estimate four crucial parameters, including the upper limit of central black hole mass M, the Doppler factor δ, the location of γ-ray-emitting region Rγ, and the propagation angle with respect to the axis of the accretion disk Φ, for more than 800 gamma-ray blazars (Pei et al. 2022, ApJ, 925, 927). We put forward an updated demarcation between BL Lacertae objects (BL Lacs) and flat-spectrum radio quasars (FSRQs) based on the relation between broad-line region luminosity and disk luminosity both measured in Eddington units, i.e., Ldisk/LEdd = 4.68 × 10−3, indicating that there are some differences between BL Lacs and FSRQs on the accretion power in the disk;

(2) We made use of information from emission lines, spectral energy distributions, and the beam radio luminosity to study the jet power, black hole(BH) mass and spin. Our results suggest that BL Lac jets are powered by extracting BH rotation energy, while FSRQ jets are mostly powered by accretion disks (Xiao et al. 2022, ApJ, 925, 40). We also claim that the launching of the relativistic jet is dominated by the Blandford-Znajek process for both FSRQs and BL Lacs (Zhang et al. 2022, ApJ, in press)

(3) By adopting a two-component model of emission within jets, we successfully separated the emission of radio, X-ray, GeV and TeV into beamed and unbeamed contributions for the largest sample of Fermi blazars up to now (Pei et al. 2020, SCPMA, 63, 25911; Pei et al. 2020, PASP, 312, 114102; Zeng et al. 2022, ApSS, in press; Zhang et al. 2022, submitted). Our results suggest that the emission is mainly from the core/beamed component in gamma-ray blazars.

KEYWORDS Blazars, Jets, BL Lacertae objects, Quasars, Black holes, Gamma-ray sources

FM 1
#789

A Simulation Study on the Morphological Dichotomy of FR-I and FR-II Jets

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Relativistic jets, emitted from the vicinity of central supermassive black holes, extend far beyond the central galaxies, up to kpc to Mpc scales. Based on radio data, these are classified into two morphological types: 1. the low-powered, center-brightened FR-I jets (FR: Fanaroff-Riley) that diffuse out into the surrounding intracluster medium, and 2. the high-powered, edge-brightened FR-II jets that remain relativistic to much larger scales. However, the reason for this dichotomy, especially the cause of the entrainment or deceleration of FR-I jets, is still not fully understood, mainly due to the complexity of the physics and the computational difficulties of simulating low-powered relativistic jets. Here, we report the results of new 3D relativistic hydrodynamic (RHD) simulations on the morphological dichotomy of FR I and II jets, injected into stratified background media, using a recently developed highly-accurate RHD code (Seo et al. 2021a). The energetics and detailed flow structures of FR-II jets were previously studied using the code (Seo et al 2021b). As an extension, we conduct a thorough multi-variate excursion of jet parameters, covering a range of jet powers between 1042 erg/s (FR-I) to 1046 erg/s (FR-II). In general, with decreasing power, the deceleration of the jet due to external entrainment becomes stronger, resulting in the FR-II to FR-I transition, as already known from previous studies. Furthermore, we find that observational effects, such as the viewing angle, time of observation, and observational resolution, are important factors in determining the FR-I/FR-II classes in simulated radio images. Additionally, the effects of source location (i.e., in galaxy clusters or in filaments) and the contribution of mass loading from stellar winds along the jet path are also examined, which should be different depending on the jet power.

Seo, J., Kang, H., & Ryu, D., 2021b, ApJ, 920, 144
Seo, J., Kang, H., Ryu, D., Ha, S., & Chattopadhyay, I., 2021a, ApJ, 920, 143

KEYWORDS active galactic nuclei, jets, numerical simulation, relativistic hydrodynamics, radio galaxies, entrainment

Baldwin Effect Study in a Sample of FSRQ-type Blazars

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In this work, we study the relationship between the 3000 Å continuum luminosity and the Mg II λ2798 Å emission line luminosity, as well as the Baldwin Effect, for a sample of 442 FSRQ-type blazars from the Roma-BZCAT Catalog. We compared the results with a sample dominated by radio-quiet quasars. Additionally, we studied whether both samples arise from the same parent distribution using a Kolmogorov-Smirnov test and found that the differences between the luminosities of the FRSQ and radio-quiet samples are statistically significant. We also found that the Baldwin Effect slope and that for the continuum luminosity - line luminosity relationship, are different for both samples. It has been previously shown in the literature that the continuum variability in the jet and disk, cannot induce a change in the slope of both relationships, under the assumption that the jet continuum does not affect the Broad-Line Region (BLR) emission. This leads us to suggest that the differences between the slopes in both samples are due to an additional line-emission region that is being ionized (either totally or partially) by the jet. We also obtained the contribution from the jet to the total continuum luminosity, using the non-thermal dominance parameter (NTD) for both samples. We separated both samples according to their NTD values, into disk-dominated, jet-dominated, and NTD < 1 (theoretically impossible according to the AGN Unified Model). We found that for the different NTD-separated samples, the slopes of the Baldwin Effect and the luminosity relationship are also different, which points to the effect of the jet in the additional line-emission region being activity-dependent. This has strong implications in the estimation of black hole masses using broad emission lines. Finally, we confirm for the FSRQ and radio-quiet sample, as well as all our sub-samples that the Baldwin Effect is a consequence of the continuum luminosity and line-luminosity relations.

KEYWORDS Baldwin Effect, Broad-Line Region, Jets, Blazars, FSRQ, AGN

FM 1
#509

Radio jets of extended sources in the Coma cluster

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We present new high-resolution, high sensitivity results of extended radio sources in a 7.5 sq. deg. region of the Coma cluster using upgraded Giant Metrewave Radio Telescope. We detected 135 extended radio sources in the 250--500 MHz band that have minimum size of 0.45 arcmin (= 12.6 kpc) at the distance of the Coma cluster with SNR > 4. Of these 135 extended sources, 24 radio sources are associated with Coma-member galaxies. We supplement 550--850 MHz uGMRT and the X-ray data for this complete sample of 24 radio sources. We present radio morphologies, radio spectra, spectral maps and equipartition properties, and we also present the roles their environments play using the X-ray data. Briefly, we find that (i) the equipartition properties lie within a narrow range, (ii) both the extended radio source sample and the RPS galaxy sample, the radio morphologies and their spectra suggest that these galaxies are moving radially toward the cluster center, and (iii) the orientation of trailing features of these galaxies suggest that they are on their first infall into Coma on (predominantly) radial orbits, We also find a diffuse "tail" of radio emission trailing the merging galaxy NGC 4789, and report transverse spectral structure, a gradual steepening from southwest to northeast across the width of the radio source/jet.

KEYWORDS Active galactic nuclei, Astrophysical black holes, Galaxy clusters, Radio continuum emission, Radio galaxies, Tailed radio galaxies, X-ray active galactic nuclei

FM 1

#459

Multiwavelength analysis of the FSRQs CTA 102, 3C 454.3 and B2 1633+382

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Blazars are a type of active galactic nuclei (AGN) that have their relativistic jet pointed towards Earth. Flat spectrum radio quasars (FSRQs) are blazars that have prominent emission lines in their optical spectrum and are extremely variable throughout the electromagnetic spectrum.

The works composing this compilation aim to help answer the questions of where the gamma-ray emission region is located and which is the mechanism that led to the production of these high energy photons in the FSRQs CTA 102, 3C 454.3, and B2 1633+382.

We studied the Mg II and Fe II emission for the first two sources and C IV for the last source, along with photometric observations of multiple bands, from radio to gamma rays.

The Mg II and Fe II lines of CTA 102 showed a response to increases of non-thermal continuum showing the existence of broad-line region (BLR) material related to the jet. The behavior of the lines in 3C 454.3 is more complex since their luminosity increases are not monotonic during the different events. Meanwhile, B2 1633+382 might not have a dense enough BLR cloud close to the jet to be easily ionized by the jet-dominated continuum.

We found the gamma-ray emission region of CTA 102 to be located at approximately 25 pc from the central engine, far from the canonical BLR. For 3C 454.3, we found that the source might have multiple gamma-ray emission regions and the dominant mechanism for their production might be changing with time. We found the gamma-ray emission region of B2 1633+382 to be located at approximately 37 pc from the jet apex and the gamma-ray event of 2011 to be possibly produced by magnetic reconnection.

Finally, the luminosity relations between the emission line and UV-continuum for the observations of these blazars mostly do not follow the expected relation for AGN radio-quiet sources. This might have an implication in the estimation of the black hole mass for FSRQs.

KEYWORDS AGN, Blazar, FSRQ, BLR, Jet, Multiwavelength, Spectra

FM 1

#420

A persistent double nuclear structure in 3C 84

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3C 84 (NGC 1275) is the radio source at the centre of the Perseus cluster and exhibits a bright radio jet. We observed the source with the Global Millimeter VLBI Array (GMVA) between 2008 and 2015, with a typical angular resolution of ~50 µas. The observations revealed a consistent double nuclear structure separated by ~770 gravitational radii assuming a black hole mass of 3.2×10^8 solar mass. The region is likely too broad and bright to be the true jet base anchored in the accretion disc or black hole ergosphere. A cone and parabola were fit to the stacked (time averaged) image of the nuclear region. The data did not strongly prefer either fit, but combined with a jet/counter-jet ratio analysis, an upper limit on the viewing angle to the inner jet region of ≤35° was found. This provides evidence for a variation of the viewing angle along the jet (and therefore a bent jet) within ~0.5 pc of the jet launching region. In the case of a conical jet, the apex is located ~2400 gravitational radii upstream of the bright nuclear region and up to ~600 gravitational radii upstream in the parabolic case. We found a possible correlation between the brightness temperature and relative position angle of the double nuclear components, which may indicate rotation within the jet.

KEYWORDS AGN, 3c84, vlbi, gmva

Direct observation of an extended X-ray jet at z=6.1

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In this talk I will present the properties of the highest redshift kilo-parsec jet of an AGN resolved in the X-rays (at z=6.1). After 20 years from the detection of the first extended kilo-parsec extragalactic jet in the X-rays, the mechanism responsible for their high-energy emission at these scales is still under debate. One of the very first hypotheses was that this radiation is produced by the Inverse Compton interaction of the electrons within the relativistic jet with the CMB photons (IC/CMB). However, several observations of jetted AGNs in the local Universe (z<1) seem to disfavour this scenario, due to the lack of a strong and permanent γ-ray emission. Nevertheless, as a consequence of the strong redshift increase of the CMB energy density (1+z)^4, we still expect this process to become important at high redshift. Indeed, from the study of the first extragalactic jet resolved in the X-ray at z>6, we find that its high-energy emission is fully consistent with the expectations from the IC/CMB model. Moreover, we also show how different types of emission mechanisms which can explain the properties of similar jets in the local Universe, are inefficient at high redshift.

KEYWORDS jets, X-ray, high-z, blazar, quasar

FM 2

Towards a World Standard for Dark and Quiet Sky Protection

Invited & Contributed Talks

FM 2

#2300

Overview of Artificial Light at Night and D&QS2 recommendations

James Lowenthal[1]

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Artificial light at night and the light pollution it produces pose a serious and growing threat to ground-based astronomy as well as to human health, the natural world, and our ability to see and enjoy the starry night sky and connect with countless generations of humans before us. I will give an overview of the status of this long-standing problem and global efforts to contain and reverse it. These include the IAU / UN COPUOS / IAC Dark & Quiet Skies 1 and 2 conferences held online in 2020 and 2021 and the resulting reports. Among the recommendations to the United Nations: 1. endorse a goal of reversing the growth of ALAN on a 10-year timescale; 2. promote the development of national and regional limits on allowable impacts of light pollution (e.g. sky glow), such as many nations already have in place to protect air and water quality; and 3. coordinate with other UN-level agencies such as the UN Environmental Program and the World Health Organization.

KEYWORDS site protection, light pollution

FM 2
#1141

Light pollution: a unified global solution is needed for a global environmental problem

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Light pollution from artificial light poses a global environmental crisis, comparable in severity to global warming by greenhouse gases, to plastics in the oceans and to industrial air pollution in many of the world's megacities. However, the dangers of light pollution are far less widely recognized, even though it is adversely impacting human health and the environment right now, as well as astronomical science.

A unified global solution is needed to address an urgent global environmental problem. There are many international agencies and organizations that can help tackle light pollution, and some are doing so already. But several more need to be lobbied. These include UNOOSA, COPUOS, IDA and IUCN (all of which are already engaged) and also WHO, ISC (the International Science Council), UNESCO and the OECD Environment Directorate. In addition, national academies of science in leading countries should be lobbied to approach their national governments.

KEYWORDS Light pollution, Global solutions

FM 2

#909

Impact of diffuse artificial light for different kinds of observations: optical wide field surveys

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I will present the findings of the impact of diffuse artificial light on existing optical, wide-field observations including the Dark Energy Camera on the 4m telescope at CTIO, as well as models and estimations for their impact on upcoming wide-field surveys such as the Vera C. Rubin Observatory's Legacy Survey of Space and Time (LSST). I will particularly consider the impact on the burgeoning field of Low Surface Brightness Astronomy from my role as tco-Chair of the LSST Galaxies' Low Surface Brightness Working Group.

KEYWORDS Diffuse Artifical Light, Light Pollution, LSST, Low Surface Brightness

FM 2
#683

The OTPC (Technical Office for the Protection of the quality of the Sky) of the IAC. Experience on Sky Law regulation

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The OTPC is hosted at the IAC - the Center that owns the Astronomical Observatories-
The OTPC is the technical office of the IAC to assure the law is fulfilled. Regarding the law, all new works that are to have lighting outdoor are to be revised before the licensee is granted and among the things to be revised is the fulfilling of the Ley del Cielo (Law 31/88 and Royal Degree 243/92 modified by Royal Degree 580/2017 - Spain).

The OTPC members do routine follow up of the lightning in the different municipalities searching for possible public or private new lighting (such as advertising lighting) to assure they have followed the prescriptions - When this is not the case they start the procedure for a fain that comes through the Industry Cancillery of the Canarian Government.

The development of new lightning systems - e.g. the more recent LED technology- imply adapting the law. For this, new regulation has to be given - The OTPC also cares for this, proposing changes to the law regulations to the Spain Government, as the recent Royal Degree 580/2017.

Proactive work is also important
They give free advice to municipalities and organisms that are to implement the new lighting so that when doing the new hardware is adapted to the law. They use strongly the argument of environmental biodiversity protection and energy (and money) saving that is a "corollary" of the application of the law.
For light makers, the OTPC does free certification of light fixtures and light sources in order to be used in protected areas.

Other impacts to be controlled by this Ley del Cielo:
Restricted airspace over observatories, in close connection with the national authorities when there is a need to fly over. Interference by electromagnetic fields, in close connection with the national authorities with periodic measurements in both observatories.

KEYWORDS Light pollution

FM 2

#937

Site Protection in Morocco: Modelling the light pollution

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Insufficient knowledge of the effects of light pollution has led to the excessive lighting of our environment. This excessive and irresponsible light has become a serious problem, having an economic as well as an environmental cost.

The work we present here assesses the current state of night sky luminosity at the Oukaimeden observatory located in the Atlas region of Morocco. Two numerical models were thus used. One uses version 2.2 of the Illumina model for artificial light. It makes it possible to provide contribution maps linking the effect of each pixel of the territory to the artificial radiance of the sky. The second uses the Gambons model for the natural luminosity of the night sky. The result of this study will help us to characterise the region's lighting infrastructure and to develop a conversion strategy for the ADSM (Atlas Dark Sky Morocco) for labelling the region as dark sky reserve.

KEYWORDS Light Pollution, Models, Dark Sky, Reserve

Protection of the dark night sky over Hawaii's observatories

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Hawaii has two main observatory sites: Maunakea on the Island of Hawaii, and Haleakala on the Island of Maui. Maunakea has been well-protected by a strong lighting ordinance that has preserved the dark night sky. Artificial light is estimated to add only approximately 2% to the natural sky brightness at the zenith. Nevertheless, population growth on the island, together with its associated lighting, brings increased challenges. The primary tools for keeping the sky dark are use of proper shielding, together with careful spectral management, including filtering of blue light from Light Emitting Diodes (LEDs). The large size of the island, together with the remote location of the observatory have helped keep the sky dark. Haleakala, originally mostly used for solar astronomy, is increasingly being used for nighttime astronomy, and hosts the Pan-STARRS telescopes, a 2-meter telescope from Las Cumbres Observatory and US Air Force Telescopes. The lighting ordinance on the Island of Maui is much weaker, and people live closer to the observatory. Haleakala is therefore not as dark as Maunakea. Although the Maui lighting ordinance requires full shielding of most lights, a loophole allowed metal halide lamps to be unshielded, and limits on blue light are lacking. Maui has numerous endangered species that are affected by light at night, including birds and turtles. Fortunately, the spectral requirements for safeguarding birds and turtles are similar to those needed for protecting the dark night sky for astronomy. New lighting on Maui is expected to be properly shielded and deficient in blue and green light, which should allow some restoration of the dark night sky over Haleakala.

KEYWORDS site protection, dark sky, light pollution, artificial light

FM 2

#2159

SAAO Site Protection against Light and Dust Pollution

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The South African Astronomical Observatory (SAAO)'s observing site near the small town of Sutherland, South Africa, is among the world's darkest astronomical observatories in the world. The night sky brightness levels at the Observatory have remained at near the same natural levels since the 1980s. The SAAO is host to more than twenty national and international optical and IR telescopes, ranging from the very small to the largest single telescope in the Southern Hemisphere – the Southern African Large Telescope (SALT). Areas that are suitable for optical and radio astronomy in South Africa are declared as Astronomy Advantage Areas (AAAs), and they are protected under the Astronomy Geographic Advantage (AGA) Act, No. 21, of 2007. Under the AGA Act, activities that pose threats to astronomy in declared AAAs are regulated as part of the Act's protection regulations. Such protection regulations have been promulgated for both radio and optical astronomies in South Africa. I will discuss the regulations applicable to the protection of optical and IR astronomy facilities in South Africa, including challenges to the regulatory implementation, monitoring of activities that cause light and dust pollution, and enforcement of the protection regulations. I will also give an update on relevant stakeholder engagements, including with the South African Civil Aviation Authority (CAA) regarding Pilot Activated Lighting, which is to be implemented, by the CAA, at the wind farms in the declared optical AAAs.

KEYWORDS Light pollution, Dust, Astronomy Geographic Advantage Act, Pilot activated lighting, Protection regulations, Optical astronomy, Night sky brightness

FM 2
#2029

Monitoring Light pollution at Kottamia Astronomical Observatory

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Light pollution is a big concern to many scientists especially astronomers, without dark skies they are unable to receive the faint signals of light from distant bodies in outer space. Many astronomical observatories are built in remote locations in an effort to escape the light of cities and towns, but since 1970s, light pollution has started to become a threat due to development and urbanization. Kottamia Astronomical Observatory in Egypt has one of the largest telescopes in Africa and the largest one in the Middle East and North Africa region. Due to the constructions of the New Administrative Capital city and other new cities around it since late 2015, the night sky brightness at Kottamia observatory has been changed due to the light of these cities. The data about the variation of the sky brightness at the location of the observatory, has been collected for the interval from April 2012 to March 2020 from VIIRS/DNB on board Suomi NPP satellite data. The data obtained for every three months are represented graphically. The effect of the sky glow over the Kottamia observatory has been studied and it is noticed that the light pollution is increasing due to spreading the light from Cairo city more than the other new cities brightness.

KEYWORDS Light pollution, sky brightness, Kottamia observatory

FM 2

#1523

Astronomical site protection in Ethiopia

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East Africa Office of Astronomy for Devt(EA-ROAD)&Ethiopian Space Science Technology Institute(ESSTI, Ethiopia

The ability of humanity to see celestial objects has rapidly deteriorated due to rising levels of artificial light pollution around the world. Nowadays a large number the world's population lives under a light-polluted sky, which limits access to dark and quiet skies for celestial object observations.

In comparison to the rest of the continent, Africa has more untapped dark sky resources and high-altitude mountains suitable for astronomical observation. However, due to a lack of public awareness and decision-makers' involvement, progress in preserving dark sky and astronomical sites for future use still at their lowest levels.

This talk will thus highlight Ethiopia's experience and progress in terms of preserving astronomical sites in particular, as well as the country's most recent progress toward dark and quiet sky activities in general. The talk will also discuss specific activities related to sites in Enoto, at the outskirts of Addis Abeba, and Lalibela in Northern Ethiopia, as well as other new sites started at Mount. Gughe and Mount. Damot in Ethiopia's southern region.

KEYWORDS Dark sky preservation, Light pollution, astronomical sites

FM 2
#2740

Starlight Foundation: Night sky preservation and local socio-economic development

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Starlight principles and recommendations are brought together in the Declaration in Defence of the Night Sky and the Right to Starlight (La Palma Declaration, 2007), in which, in addition to the IAC, representatives of UNESCO, UNWTO, IAU, UNEP-CMS, CE, SCBD, COE, MAB and the Ramsar Convention all participated and launched Starlight as an international movement in defence of the sky by night and day and to treat it as a source of knowledge and culture that should be shared with society as a whole, promoting the dissemination of astronomy and sustainable, high-quality tourism in those places where the night sky is cared. The Starlight Reserves, Tourist Destinations and other modalities are scenarios that incorporate the observation of the sky as part of the natural, scenic, cultural and scientific heritage and encourage star tourism, promoting infrastructure, products, activities and training of specialized guides in the field of sustainable tourism. The Starlight Foundation leads the UNWTO Affiliate Member Working Group on Scientific Tourism. The main purpose of this group is to explore the potential of this branch of tourism, as well as to create a forum where ideas and experiences about combine Science and Tourism are studied and contrasted, starting with the astro-tourism. Starlight sites, along with IDA and RASC dark sky sites, have been named Dark Sky Oases in the recommendations report produced at the "Dark and Silent Skies for Science and Society" workshop organized by the United Nations Office for Outer Space Affairs and Spain, jointly with the International Astronomical Union and the Instituto de Astrofísica de Canarias, held in October 2020. The main objective was to recommend to COPUOS the consensus levels of sky brightness considered appropriate for the different classes of dark sky oases, as defined by the IUCN Dark Skies Advisory Group. This presentation will summarize current Starlight projects and best practices for sky protection and astro-tourism.

KEYWORDS Light Pollution, Starlight, Astro-tourism, Dark Sky Oases, Sustainable development, ALAN Regulation

FM 2

#1200

The status of light pollution in Japan and its relation to astro-tourism

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The following is an overview of topics related to this session over the past few years in Japan.

1. The severity of light pollution has improved in urban areas in Japan compared to during the 20th century. The Ministry of the Environment of Japan encourages citizens to measure the brightness of the night sky every summer and winter for the purpose of air quality conservation. Nagano Prefecture declared "Nagano is a Cosmic Prefecture" in 2016, and light pollution surveys are now conducted in almost all municipalities. Nationally, the voluntary organization "Starry Sky Public Corporation" plays an important role in light pollution prevention and light pollution impact studies. https://uchuuken.jpn.org/keizoku/index.html (Japanese only)

2. Meanwhile, astro-tourism is becoming more and more popular in Japan, and in 2017, the national organization "Sora Tourism Promotion Council" was established with support from the Japan Tourism Agency. It also contributes to the prevention of light pollution in cooperation with the Ministry of the Environment. https://soratourism.com/language/en/

3. IDA's International Dark Sky Places are being recognized one after another in Japan, and currently three locations have received certification. Tokyo Chapter, International Dark-Sky Association plays a central role in this activity. https://idatokyo.org/hogoku (Japanese only)

4. In 2019, the Spectrum Management Office was established at NAOJ. In addition to frequency protection in radio astronomy, the office also works to prevent light pollution by studying the effects of the Starlink satellites. https://prc.nao.ac.jp/freqras/EN_index.html

KEYWORDS light pollution, astro-tourism, Sora Tourism, International Dark Sky Places, Nagano, Bisei, Ishigaki Island

FM 2

#2490

IDA's international program for dark sky preserves as a model

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The International Dark-Sky Association now recognizes more than 200 International Dark Sky Places worldwide, with at least as many places currently pursuing recognition. While every place is unique, they have all been through a rigorous certification process and are required to submit annual reports. The program recognizes best practices in five areas: sky quality measurement, lighting policies and plans, quality outdoor lighting practices, restoration projects, and public education.

Several of the places in the program protect world-class observatories - like Mont-Mégantic in Canada, the first International Dark Sky Reserve, and Warrumbungle National Park, the first International Dark Sky Park in Australia. But most of the 200 places are not motivated by astronomical concerns. But instead, the multitude of other values of naturally dark skies. Values like wildlife conservation, protecting the heritage of a region, or promoting dark sky tourism. As light pollution grows worldwide, these place-based demonstrations of dark sky protection are becoming important motivators for action in light pollution control at a regional and national level. We'll explore lessons from the International Dark Sky Places program and discuss how a commitment to place-based dark sky protection can slow, stop, and ultimately reverse the growth in light pollution.

KEYWORDS Dark Sky, Light Pollution, Conaservation

FM 2

#2196

Modeling to Mitigate the Impact of ALAN

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Light pollution modelling aims to reproduce and predict how artificial light affects the sky by simulating the interactions between electromagnetic radiation and the atmosphere. That interaction depends on multiple variables such as air mass, atmospheric content, altitude, direction, light spectrum, cities architecture, ground surface, etc. As a general rule, light pollution models have to balance its completeness and precision with the time needed to make the simulations.

Using sky brightness models have three advantages with respect measurements when trying to reduce light pollution. First, they help us to understand the phenomena in a physics level, i.e. the role that each variables plays. That knowledge allows focusing on the correct variables when trying to reduce the harmful effects of light pollution. Second, it is possible to point out where the artificial radiance received is coming from. Guiding us to make changes in the sources that matter most. Finally, they provide predictions. That means that several lighting systems can be simulated beforehand enabling to study their consequences without having to actually install them.

In order to demonstrate the utility of sky brightness models in the battle against light pollution two different studies are going to be presented. The first one shows how to spot the main sources of light pollution. The sky over several locations has been studied to point out the impact that every source is responsible for. The second study is a zenith sky brightness map of a Spanish province of 6000 km2. Several lighting systems have been used to show how the sky would change if they are implemented.

Both studies have been done using the light pollution model Illumina. This model lays in the complexity end of the balance stated previously between completeness and time needed to perform simulations. The study of the source contribution has been done with a simplification of that model. The zenith sky brightness map, on the other hand, has been created with the full capacity of Illumina. Each map created needed a computing time of 150 000 CPU hours approximately.

KEYWORDS Simulation, Modelling, Light pollution, Radiative transfer

FM 2

#602

Measurement for Regional Monitoring

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The study of the impact of Artificial Light at Night in the quality of the night skies has a priority tool: measurements. These measurements could be done using remote sensing techniques as satellite, drones or similar flying devices or could be done at regional and local scale with direct mesurements of the night sky brightness from the ground. In this talk I will summarize the most relevant techniques of ground measurements, these are mainly the use one direction devices (SQM, TESS-W) and all sky systems (ASTMON, SQC). With the combination of these system a wide study of the night sky quality could be done in local and regional scale as the case of Catalonia region (Spain) that is used as a case study in this presentation.

KEYWORDS light pollution, site testing

FM 2
#1558

The Gaia4Sustainability project: assessing light pollution aided by natural night sky brightness modelling

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The presence of excessive artificial lighting at night and the consequent disruption of the natural day-night cycle has a pernicious effect on many species. To obtain reliable measurements of the light pollution levels, it is mandatory to know the natural night sky brightness including the integrated star light, zodiacal light, the galactic and extragalactic background light, and the airglow. This together with a model of the terrestrial atmosphere extinction and scattering provides a realistic image of the night sky for a given place and time. High quality photometry provided by the (ESA) Gaia satellite allows to compute the contribution of the integrated star light. The resulting model can, then, be used as a reference value of the natural sky brightness (in cloudless nights), or to know the expected natural levels of sky brightness at pristine areas.

Our project also aims to develop a robust, reliable, and straightforward framework for estimating the sky brightness. It consists in a set of implementations (web service, stand-alone program and open-source measurement device) devised for any interested stakeholder to accurately evaluate the impact of light pollution –on, for example, environmental activities. The framework includes the design and construction of a cheap and easy-to-build photometer, named FreeDSm, based on open software and low-cost hardware. It will include several connectivity options and the ability to collect positioning information and measure light pollution, being capable to share the data on the platform, if desired. Currently, FreeDSm is based on a Raspberry Pi Zero and on an Adafruit TSL2591 module, although additional and optional modules will follow.

This twofold methodology (modelling and low-cost measuring) proposed by Gaia4Sustainability, intends contributing 1) to widely spread the acquisition of measures; 2) achieve a greater engagement of social agents; and 3) rise generalised awareness on the light pollution problem.

KEYWORDS light pollution, Gaia data, radiative transfer, instrumentation: photometers, modelling, natural sky brightness, IoT

FM 2
#1401

Legal protection of dark skies above major observatories

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Light pollution is a fast-growing environmental problem that is caused by the increased amount of artificial light at night (ALAN). Light pollution is a hazardous stressor for various areas, especially for astronomy. Professional and amateur astronomers were the first advocators of dark sky protection. Their active actions have resulted in the development of the first legal instruments for the reduction of ALAN. The aim of this article is to analyse the existing legal instruments for the protection of natural dark skies above the major observatories. This article is intended to provide an overview of current legal regimes, indicating legal instruments and measures adopted for the normal exercise of astronomical activities.

Light pollution is a stressor for many areas, however, the most adverse effects are faced by astronomical activities. Since the middle of the 20th century, astronomers were advocating the protection of the natural dark skies to be able to properly exercise their amateur and professional activities. Active actions of astronomers have resulted in the development of varied legal instruments and guidelines, aiming to mitigate increased artificial night-time illumination. This article will identify the legal regime for the protection of dark skies above major observatories by undertaking analysis and overview of existing legal instruments and measures. The article is intended to contribute to filling a gap in legal research related to the legal protection of the dark skies from ALAN as an adverse anthropogenic factor. Additionally, this article will facilitate the understanding of legal regimes and legal measures taken in order to preserve the dark skies for astronomical activities.

KEYWORDS light pollution, international environmental law, dark-sky protection

FM 2

#2452

Applying astronomical techniques to characterize ground-based light pollution sources

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The effects of light pollution by artificial ground sources increasingly impact the quality of the night sky for humans, biodiversity, and astronomy. Although a worldwide problem, Chile is disproportionately affected by light pollution due to the high concentration of the world's leading observatories. In order to minimize these effects, Chile has introduced emission standards with the aim of reducing light emissions to the sky and to promote the use of technology that does not emit outside the visible spectrum, which otherwise would hinder astronomical observations.

We present the first preliminary results of our pilot project (supported by the ESO fund 2020), which aims to test the effectiveness of emission standards set by the Chilean government by creating a detailed light emission survey of the Antofagasta urban city and surrounding area using an Unmanned Aerial Vehicle (UAV). If successful, this method can provide a cost-effective and efficient path to assess and mitigate the effects of ground-based light pollution sources in astronomical hubs all around the world.

KEYWORDS Light pollution, Photometry, Survey

FM 2
#2356

The Chilean Norma Luminica and the Research Group on ALAN

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Light pollution is a phenomenon on a global scale, affecting astronomy and like any other form of anthropogenic pollution, heavily affects ecosystems and causes adverse health effects. The main threats are over lighting, light emissions over the horizon of sport venues and advertising, in addition to the massive use of cold LED sources. To face these new threats to dark skies and biodiversity, a new light pollution norm has been developed to drastically reduce the blue component of the spectral radiance of outdoor lighting, incorporating also new regulations for industrial, sports and ornamental lighting. As now its main justification is environmental, it has also also been decided to extend the application of the norm to all of Chile.

Almost in paralell, a recent modification of the Chilean environmental framework law has incorporated the concept of artificial light into the definitions of polluting elements, and has also incorporated the areas of astronomical value with scientif purposes to the list of relevant environmental components. With this improvement, the cumulative effect of light pollution must be evaluated in the environmental impact assessment system run by the Environmental Assessment Service.

In this contribution there are presented both the new light pollution norm and the modification of the enviromental law to incorporate the concept of artificial light and also it is introduced the NOIRLAB-ULS-OPCC Research Group on ALAN by describing its raison d'être; its short, medium and long-term goals; the first results of its monitoring campaigns across the Coquimbo Region in Northern Chile; and, finally, its synergy with the existing public and private institutions that are tackling the same cross-cutting issue from different perspectives.

KEYWORDS light pollution, spectral radiance, ALAN, environmental impact, outdoor lighting, Norm

FM 2

#2319

Radio astronomy and the quest for Quiet Skies

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The radio spectrum is a very scarce and valuable natural resource, internationally managed by the ITU-R (a specialized agency of the United Nations) and nationally managed by national radio agencies. The spectrum is divided into relatively small bands, where radio astronomy has allocated about 2% of it below 86 GHz and about 12% from 86 GHz to 200 GHz. But the advancement of receiver technologies and astronomical techniques have allowed the use of receivers that cover large swaths of spectrum, enabling new science and higher sensitivities, but increasing the potential for receiving interference.

The ITU-R defines the rights and obligations of each spectrum user, assigning specific frequency bands and ensuring that it will be able to operate without interference but also with the requirement to avoid producing interference to another user. The needs of radio astronomy for very clean spectrum bands and also wider observing bands, collide with the operation of other spectrum users whose signals can be millions of times stronger than astronomical sources and who are constantly looking to use more spectrum creating an ever increasing pressure on passive services such as radio astronomy.

In this presentation the constant search for a quiet sky will be discussed, starting with how radio astronomy sees the radio spectrum and how other spectrum users see it. The international spectrum management landscape, and how radio astronomy fits in it, will be presented with some examples, covering the different uses of the spectrum (Passive, Active) and the allocation of frequency bands (primary, secondary, passive band), including how radio astronomy makes observations outside of these bands in an opportunistic mode.

The importance of the protection of the frequency bands allocated to radio astronomy will be highlighted, which are the ITU-R protections and what can be expected of them. Special emphasis will be made on how every radio astronomer can help to protect these very special bands which are constantly under pressure.

KEYWORDS radio astronomy, Quiet skies, ITU, Spectrum management, RFI

How radio frequency interference affects astronomy

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Radio frequency interference (RFI) by artificial sources has since long been widespread enough and has had a wide enough range to threaten the scientific work of radio astronomers, also owing to the extreme sensitivity of radio telescopes. For this reason, radio astronomy is actively engaged in frequency management, i.e., the protection of radio science by regulation. But this task is becoming increasingly difficult, as the radio spectrum is an extremely scarce resource and pressure is high to allocate more and more frequencies to radio services making use of their frequency windows as efficiently as possible. This in turn means that the successful operation of radio telescopes gets more and more restricted to the few radio windows reserved for "passive" scientific applications. Even those last quiet islands are under pressure, and schemata are being discussed to share passive frequency windows with commercial applications by coordination. The radio transmission on earth has constantly increased with time and this poses a problem. But particularly the use of satellites or high-altitude radiocommunication platforms affects radio astronomy, as both communicate actively by using strong radio waves sent to earth from above. As a consequence, the scientific scope of radio astronomy is decreasing. While radio continuum science is mostly affected in terms of sensitivity, as less bandwidth is becoming available to integrate the signal, some line observations have been made impossible or are threatened. In this presentation I will discuss how RFI has increasingly affected astronomical radio observations and the scope of RFI mitigation. I will then address possible (near) future threats and attempt to discuss whether there is a way forward for radio astronomy in the light of the progress of harmful RFI.

KEYWORDS Radio frequency interference, Radio astronomy

FM 2

#2878

Endangered frequency bands

L. Viktor Tóth[1]

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I will flesh up the types of major threats on specific astronomically important frequency bands by ground based, arial and space services. Starting from low frequencies utilised by LOFAR and SKA through important continuum and spectral lines of dm and cm wavelengths up to the mm spectroscopy will be reviewed. There are well spread and recently introduced services as well as new plans which may endanger radio astronomy. While we may handle the situation filtering out radio frequency interference (RFI), a few effects may completely falsify measurements or propose threats on our sensitive devices. Examples will be shown to demonstrate how serious the situation is.

KEYWORDS radio astronomy, RFI, radio continuum, radio spectroscopy

Managing Radio Frequency Interference at the Giant Metrewave Radio Telescope

Divya Oberoi[1], Pravin Raybole[1], Ankur Prajapati[1], Sanjeet Kumar Rai[1], Sureshkumar S.[1], Shriharsh Tendulakar[2], J. K. Solanki[1], Yashwant Gupta[1]

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Modern radio instruments across the world are moving towards wider bandwidths in their quest for higher sensitivity. At the same time, the utilization of spectrum to accommodate our growing communication and technological needs with attendant benefits to society has been growing and the pace has accelerated dramatically in recent years. Driven by the necessity to shield themselves from the intentional and unintentional radio emissions, many of the radio telescopes are located in sparsely populated areas, where it is feasible (though with considerable effort) to establish large radio quiet reserves. There are also major facilities like the Giant Metrewave Radio Telescope (GMRT) which are located in comparatively populated areas where the approach of establishing a radio quiet zone is impractical. At the GMRT, we have successfully been following a co-existence model for limiting the radio frequency interference (RFI) in the part of the band used for GMRT observations, by looking for ways to meet the needs of other stakeholders while maintaining low levels of RFI around the GMRT. This presentation will give a glimpse of the various aspects of the efforts being put in towards this end. In addition to comprehensive efforts directed towards RFI flagging, excision and avoidance, key aspects of this effort include - (1) engaging with the policy makers and central Government agencies for obtaining and ensuring continued RFI protection from intentional RFI sources (e.g. telecom service providers) especially with the imminent roll out of 5G technology; (2) working with the local Government agencies responsible for distribution of power and issuing the necessary permits to industries being set up in the neighborhood of the GMRT; (3) vigilant monitoring to quickly become aware of new RFI sources; and (4) working with neighboring industries and farmers to minimize unintentional RFI by identifying and suggesting EMC compatible products and devising shielding solutions.

KEYWORDS Instruments: Interferometry, Instruments: Radio, radio frequency interferometers

FM 2

#1653

Update on Activities of The US National Academies' Committee on Radio Frequencies (CORF)

Karen Masters[1]

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The standing Committee on Radio Frequencies (CORF) of the US National Academies of Science, Engineering and Medicine (NASEM) considers the needs for radio frequency requirements and interference protection for scientific and engineering research, and represents the views of the U.S. scientists working both Earth Exploration-Satellite Service (EESS) and Radio Astronomy Service (RAS). CORF monitors and responds to radio frequency interference and allocation issues as they arise, for example by filing comments before the Federal Communications Commission (FCC). CORF was established in 1961, and is sponsored by NASA and NSF.

Representing the members of CORF, we give an update on committee activities, and discuss the recent report from the National Academies detailing views on agenda items for the 2023 and 2027 World Radio Communication Conferences (WRC-23 and WRC-27).

Current Committee Members:
CHAIR: Nathaniel Livesey; VICE CHAIR Scott N. Paine.

MEMBERS Nancy L. Baker, Laura B. Chomiuk, Dara Entekhabi, Philip J. Erickson, Kelsey Johnson, Christopher Kidd, Karen Masters, Mahta Moghaddam, Frank K. Schinzel

KEYWORDS radio astronomy, radio observing, regulations

FM 2

#1991

Characteristics of Radio Quiet Zones

Carol Wilson[1], Gayathri Kongara[1]

[1]Space & Astronomy, CSIRO, Australia

On the one hand, a radio quiet zone can be defined simply as an area within which man-made radio emissions are limited so that sensitive radio astronomy observations can be made with minimal interference. On the other hand, countries around the world have taken various approaches to defining – and maintaining – radio quiet zones, so there is no single model to describe them all.

This presentation will discuss a range of considerations in establishing a radio quiet zone, including geographical, technical, economic and political issues, as well as the requirements for ongoing monitoring and maintenance. Numerous examples of the control measures used at established radio quiet zones will be presented, such as dealing with licensed radio transmitters, unlicensed transmitters, incidental emissions, self-interference and aircraft.

The presentation will draw on Report ITU-R RA.2259 "Characteristics of Radio Quiet Zones" and discuss future directions for international regulatory discussions on radio quiet zones. Finally, the authors will describe their experiences in managing a large radio quiet zone in Western Australia.

KEYWORDS Radio astronomy, radio quiet zone, interference

FM 2

#700

Recent Progress on Proposed National Standard of Electromagnetic Environmental Protection for Radio Telescopes

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The radio astronomical observations which detect extreme weak radio signals from the universe are vulnerable to the radio frequency interferences (RFI) from all kinds of man-made sources, whatever intentional or unintentional. In the past decade, radio astronomical facilities in China has seen been developed rapidly. For instance, the 500-meter Aperture Spherical radio Telescope (FAST) has detected around 500 new pulsars and made outstanding outcomes in FBR research. On the flip side, due to the booming economy and society, especially the surging telecommunication services, the electromagnetic environments around the radio telescopes are getting worse. Both astronomers and radio governors have realized that it is imperative to formulate a national standard to ensure the protection of radio telescopes from RFIs and the enforcement of spectrum management.

Since 2019, the draft of national standard named technical specifications of electromagnetic environmental protection for radio telescopes has been proposed. Based on ITU Radio Regulations and associated recommendations, People's Republic of China Regulations on the Radio Frequency Allocation and the national standards, the draft standard on protection requirements have been studied and harmful RFI thresholds have been given in the bands from 30 MHz to 275 GHz. Meanwhile, the measuring methods for radio environment around telescope have also been developed.

The application of the national standard was submitted to the Standard Administration of China in December 2019 and the two-year standard drawing began in August 2020. Based on a lot of discussions and coordination, the draft standard has been revised and updated. In February 2022, the draft standard was released in the website of the Standard Authority to solicit public opinions in and will be subject to higher-level scrutiny. Meanwhile, the text of the draft standard remains consecutive refine tuning until it gets ratified.

KEYWORDS Radio telescope, RFI, National standard

FM 2
#2889

Radio Astronomy Dynamic Coordination Zones

Bevin Vanderley[1]

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The U.S. National Science Foundation has initiated a funding program to catalyze and advance dynamic spectrum sharing. We will present an overview of the program and the possibility this approach presents for maintaining vital spectrum access for astronomical research for decades to come. Ongoing technological progress has created a situation where each application, activity, and service seeks additional spectrum access. Potential benefits from additional spectrum access include faster communications, new astronomical and scientific discoveries, more energy-efficient cities, increased highway capacity and safety, and more accurate weather predictions. Many spectrum management techniques are currently manual with timescales not conducive to dynamic sharing. Moving to a more automated, real-time spectrum management approach may enable diverse spectrum users to safely operate closer together in space or frequency or to trade spectrum access more rapidly than is possible with traditional spectrum management approaches.

KEYWORDS spectrum management, radio, techniques, instrumentation

FM 2

#895

Overview of the Impacts from & Mitigations of Satellite Constellations on Optical Astronomy

Constance Walker[1], D&QS[1]&[2] & SATCON[1]&[2] Working Group Chairs & Members[2]

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[2]*., ., United States of America*

Future large constellations of bright satellites in low-Earth orbit (LEOsats) will fundamentally change observational astronomy at optical wavelengths. Nighttime images without satellite trails will no longer be the norm. If the 70,000+ LEOsats proposed are deployed, no combination of mitigations can fully avoid impacts of satellite trails on science programs of ground-based optical astronomical facilities. Astrophotography, amateur astronomy, & the experience of a starry night sky are already affected. The reports from the Satellite Constellations 1 (SATCON1) & the Dark & Quiet Skies for Science & Society (D&QS1) workshops in 2020, support these statements. The aim of SATCON1 & the Satellite Constellation Working Group (WG) of D&QS1 was to better quantify the impacts of LEOsat constellations, explore possible mitigations & make recommendations.

Mitigation strategies for the most damaging impacts on scientific programs are being actively explored by astronomers worldwide & have benefited from collaboration with industry. SpaceX has shown that operators can reduce reflected sunlight through satellite orientation, sun shielding, & surface darkening. A joint effort to obtain higher accuracy public data on predicted locations of satellites could enable some pointing avoidance, & mid-exposure shuttering during satellite passage. Observatories need to adopt more dynamic scheduling & observation management, where effective.

For these reasons, the SATCON2 workshop & D&QS2 conference in 2021 utilized the SATCON1 & D&QS1 recommendations, forming pathways to feasibly employ mitigation solutions for observatories & industry. The SATCON2 Community Engagement WG brought many new voices & perspectives to the issue. Both Policy WGs examined regulatory framework & mitigation approaches from national & international viewpoints. The results laid the foundation for the IAU Center for the Protection of the Dark & Quiet Sky from Satellite Constellation Interference launched in April 2022.

KEYWORDS satellite constellations, observational astronomy, brightness mitigations, trail prediction/mitigations, policy/regulatory frameworks, community engagement, partnerships with industry

FM 2
#2320

Large LEO satellite constellations: Prospects for interference and threats to radio astronomy

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The deployment of large LEO satellite constellations pose a significant change in the way radio astronomy will see the sky. While the terrestrial use of the radio spectrum (like for example the user terminals of these constellations) can be coordinated at a national level, with more or less protections from the national radio administrations, space transmissions are coordinated at international level. With current deploying constellations representing more than half of the operational satellites around the Earth, and planned constellations that may result in more than 2000 satellites above the horizon (i.e. visible for radio astronomy) at any moment in time, radio astronomy is facing several challenges.

First is the potential to have radio astronomy protected bands impacted by spurious emissions of adjacent (or nearby) downlink transmissions from the constellations. Current frequency plans could potentially affect the primary bands: 10.6-10.7 GHz (reserved for continuum observations including a purely passive part in 10.68-10.7 GHz protected by the RR No 5.340), 22.21 - 22.5 GHz (together with its extension 22.01-22.21 GHz listed under RR No 5.149 to detect red-shifted H2O emissions), and higher frequencies as 42.5 - 43.5 GHz and 76 - 77.5 GHz.

Apart from the potential impact on these primary bands, wideband receivers may be also impacted. Receiving very strong interference signals, when including the frequency range of satellite downlinks, that could generate non-linearities or saturation effects resulting in the loss of the total bandwidth of the receiver. This will have a data-loss effect that will increase with the density of satellites in the sky.

As a secondary effect, unintended electromagnetic emissions (or commonly referred to as “electrical noise”) of a very large collection of satellites could surpass the protection levels for radio astronomy. Similarly, if the satellite density is high enough, reflections from powerful ground transmitters could be detected by radio telescopes.

Addressing these risks for radio astronomy requires a broad approach, not only at national and international level in spectrum management, but also in direct collaborations with industry and recently in the UN COPUOS in discussions about Dark and Quiet Skies and Long Term Sustainability of Space.

KEYWORDS radio astronomy, megaconstellations, starlink, oneweb, ITU-R, COPUOS

FM 2

#1601

Quantifying the effect of satellite constellations on optical observations

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We quantified the impact of large satellite constellations on astronomical observations in the visible and infrared domains, considering the characteristics of a series of representative instruments: imagers, both classical and wide-field; spectrographs, low- and high-resolution, long-slits and fibre-fed; we consider small to large professional telescopes, including the upcoming extremely large telescopes currently under construction.
Using a fast yet accurate analytical representation of the satellite constellation, we compute the impact of the satellites over a wide range of parameters: time of the night, season, observatory latitude, elevation and azimuth of the observation, and exposure time. The brightness of the satellites is computed using a simple but conservative model tied to recent observations of Starlink and OneWeb satellites.
We confirm and refine earlier results (Hainaut et al, 2020, Bassa et al, 2022):

High-altitude constellations (>1000km) are considerably more damaging than low-altitude ones, even if they include significantly fewer satellites.
Observation contamination occurs essentially during the first and last hours of the night. During summer nights, however, high-altitude satellites will affect observations during the whole night.
The impact scales with the field of view: wide-field imagers are much more affected than traditional imagers and spectrographs (including multi-fibre spectrographs). The worst impact is on wide-field camera on a large telescope.

Counter-intuitively, longer exposures are less sensitive to satellites than shorter ones.
Most spectrographic observations are not sensitive to satellites. In particular, high-resolution spectrographs (including on large telescopes) are blind to satellites. However, for affected spectrographs, the contamination will be at a level similar to that of the scientific targets.
Exoplanet transits are not affected thanks to the small effective field of view of these observations, and to the extremely short duration of the eclipse by a satellite.
Thermal IR observations are protected by the instrument small field of view and observation techniques.
We also hint at some mitigation techniques based on our simulations.

KEYWORDS light pollution, site testing, space vehicles, telescopes, surveys, satellite constellations

FM 2

#1493

The Opticon-Radionet effort towards the protection of the dark and quiet skies

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The Opticon-Radionet Pilot (ORP) project is a relatively young project under European Union's Horizon 2020 research and innovation programme, with the objective to harmonise astronomical research in Europe. Its 37 partner institutes constitute a major part of European optical and radio astronomy. A setup like this cannot neglect the increasing threats to astronomy coming from light pollution and radio frequency interferences. Therefore, as a joint activity inside the project, we started a programme to address both technical solutions and intervention activities to protect astronomy from the harmful interference through artificial electromagnetic radiadion or electromagnetic interference (EMI). The tools that we want to strengthen within the scope of the partner institutions comprise efficient community networking, public awareness-rising, building of advocacy tools, and the creation of software and hardware to monitor and mitigate EMI. The activity does not aim at addressing these tasks globally, but is rather tuned towards the specific community and political landscapes of the ORP partner organisations. We hence aim at channeling our own efforts into the broader initiatives by the international astronomical community like the IAU Center for the Protection of the Dark and Quiet Sky from Satellite Constellation Interference or the IAU groups engaged in Dark & Quiet Skies Protection. Here, we give an overview about the aims and status of the activities.

KEYWORDS

FM 2

#690

The IAU Centre for the Protection of Dark and Quiet Sky from Satellite Constellations Interference (IAU CPS)

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[2]*CPS, NSF NOIRLab, United States of America*
[3]*CPS, SKAO, United Kingdom*

The deployment of large communication satellite constellations in Low Earth Orbit represents a serious threat to the astronomical observations, both in the optical/IR and radio wavelength bands. The Workshops "SATCON" 1 and 2 and the Conferences "Dark and Quiet Skies for Science and Society" I and II have analyzed in detail the negative impact of the constellations and have suggested a number of mitigating measures and strategies. The mission of the IAU CPS, which begins its operation on April 1st, 2022, is to coordinate the implementation of the recommended measures with the contribution of the astronomical community and of the industrial stakeholders. The paper will describe the Work Plan of the IAU CPS as well as the procedure for contributing to its realization in its four areas of activities or "hubs": Satellite constellations, Industry & Technology, Policy & Regulations and Community Engagement.

KEYWORDS Dark and quiet sky, Satellite constellation interference

#2227

SatHub - A Community Driven Observation Portal of the new IAU Centre for the Protection of the Dark and Quiet Sky from Satellite Constellation Interference

Siegfried Eggl[1], Meredith Rawls[2], Samantha Lawler[3], Constance E. Walker[4], Piero Benvenuti[5], Federico di Vuro[6]

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[4]NOIRLab, National Science Foundation, United States of America
[5]Dipartimento di Fisica e Astronomia "Galileo Galilei", University of Padova, Italy
[6]SKAO, SKA Observatory, United Kingdom

The recent challenges astronomy is facing in light of the tens of thousands of satellites being launched into Low Earth Orbit (LEO) are best tackled as a coordinated, international effort. Recognizing the need for a platform that addresses those challenges, the IAU has created the new IAU Centre for the Protection of the Dark and Quiet Sky from Satellite Constellation Interference (CPS). SatHub is a community driven public facing portal of the CPS. The main components of SatHub are Astronomical Data Repositories, an Orbital Solution Portal, Software Tools, a Training Curriculum, and support for Real-Time Collaboration. Each of these encompasses several critical modules — everything from image databases to a developer guide for software contributors, to quick start recipes for observers equipped with various hardware, to a mechanism for submitting requests to observe satellites. This presentation will describe initial work in three key SatHub aspects and outline areas where additional community contributions are needed. We are working towards enabling broad participation in SatHub in order to minimize duplicated effort and disseminate information on a rapidly changing LEO satellite population.

KEYWORDS SatHub, IAU CPS, Centre for the Protection of the Dark and Quiet Sk, LEO, satellite interference, quiet sky, artificial satellites

FM 2

#1070

Software needs to mitigate the satellite constellation challenge

Jonathan McDowell[1]

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The astronomical community will need to develop software tools to help it continue to do ground based astronomy in the era of ubiquitous satellite constellations. I will report on the recommendations of the SATCON2 Algorithms Working Group. We explored needs for satellite pass prediction and observation scheduling (PassPredict), image trail masking and characterization (TrailMask), and for simulations of the overall effects of satellite constellations. The SatHub element of the IAU Center for the Protection of the Dark and Quiet Sky from Satellite Constellation Interference will host relevant software developed by the community.

KEYWORDS Light pollution, Satellites

National Policy and Regulations

Richard Green[1]

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A key function of the IAU Centre Policy Hub is to facilitate the adoption of national regulations to mitigate the impact of satellite constellations on astronomy that achieve a consistent international goal. Each major spacefaring nation has its own particular regulatory approach to licensing launch and operations. Although no nation yet has a comprehensive full lifetime framework from launch to deorbit, many have implemented favorable policies for specific aspects of mitigation. We will take a brief world tour to explore how countries are starting to protect their observatories and force consideration of astronomy as part of the regulating of low earth orbit constellations.

KEYWORDS Satellite Constellations, Site Protection, Law and Policy

FM 2
#2633

The Industry hub of the IAU Centre for the Protection of the Dark and Quiet Sky

Tim Stevenson[1]

[1]Assurance, SKAO, United Kingdom

The IAU Centre provides a nexus for the sharing and co-ordination of technical and operational solutions that may be implemented by constellation and other operators in mitigating the effects of satellite deployment and operations. The presentation will discuss how the interchange is working between the community and industry, along with a description of proposed measures, the results of analyses and trials, and the commitments made by industry towards a sustainable set of solutions.

KEYWORDS Dark sky, Quiet sky, satellite design, satellite operations

FM 2
#2531

Community Engagement

Jessica Heim[1]

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Since the launch of the first Starlink satellites in 2019, the professional astronomical community and several satellite operators have been in dialogue about finding ways to reduce and mitigate the challenges satellite megaconstellations pose to astronomy. The SATCON1 (held in 2020) and Dark and Quiet Skies I-II (held in 2020 and 2021) workshops were focused on better understanding satellite constellation impacts on astronomy and finding possible solutions to address these issues. Initially, the main stakeholders involved in these initiatives were professional astronomers and satellite operators. However, changes to the night sky and Earth's orbital environment affect all of humanity.

To include a broader array of stakeholders in discussions about megaconstellation impacts, the SATCON2 workshop (held in 2021) included a Community Engagement Working Group. This Working Group's task was to "engage a wide set of constituents in our shared goals for dark skies and a sustainable presence in space," and to "lay a foundation for ongoing communication and collaboration to preserve space as a scientific, environmental and cultural resource for humanity." (https://aas.org/satellite-constellations-2-workshop)

This working group reached out to amateur astronomers, astrophotographers, and astrotourism professionals in order to learn more about satellite impacts on their activities. It also engaged with individuals from several Indigenous nations, seeking to better understand their perspectives and concerns about changes to the night sky and the nature of the emerging space economy. In addition, it began to examine environmental and social justice issues arising from increased launches and other space sector activities.

The Community Engagement Hub of the IAU Centre is continuing and expanding the work begun in SATCON2. This talk will focus on what this Hub has accomplished in the first few months since the creation of the Centre.

KEYWORDS Culture, Dark Skies, Environment, Indigenous Communities, Satellite Constellations, Society

FM 2

#859

Educating and empowering astronomers with SatHub

Fatoumata Kebe[1], Vayujeet Gokhale[2], Meredith Rawls[3], Jeremy Tregloan-Reed[4], Federico Di Vruno[5], Sandor Kruk[6], Stella Kafka[7], Darcy Barron[8], Mike Peel[9], Elena Cirkovic[10], Samantha Lawler[11], Olga Zamora[9], Doug Knox[12], Matthew Goodman[13], Harry Krantz[14], Ian Birdwell[8], Tim Deck[15]

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SatHub will be the future online hub dedicated to quantify and catalog various observational parameters (timing, satellite brightness, location, velocity, etc.) of artificial objects evolving in the Low Earth Orbit (LEO). This will support the planification of observations such as the best window time where the data collected will be the least impacted by the passage of the satellite constellations.

SatHub will also contain modules introducing key subjects linked to the space sector like space law. This curriculum will give enough tools to the astronomical community to understand and deal with the space community.

Secondly, to function smoothly and to be able to adapt its future functionalities with the fast-changing LEO environment, a key piece of SatHub will include trainings for each type of observations for both professional and amateurs astronomers and citizen scientists to contribute to the global LEO monitoring campaign.

In this presentation, we will introduce the curriculum of the educational part of SatHub.

KEYWORDS DarkSky, Education, SatHub, Low Earth Orbit, Space Industry

FM 2

#529

Dark Skies and Bright Satellites

Priya Shah[1]

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We have reached a strange situation in time. Space technology which was originally driven by the quest for the stars and space has reached a point where it threatens our view of the skies and observations by ground-based telescopes. The first mass launch of 60 Starlink satellites on 23 May 2019 by SpaceX, shocked astronomers all round the world with the obvious threat it posed to clear, dark skies. On the one hand, is the promise of broadband internet to underdeveloped and unaccessible areas of the globe, and on the other hand the brightly lit sky with trails of thousands on satellites is a heavy price and threat to all ground-based and space-based observations. These `megaconstellations' will flood the skies in the near future and are a threat to astronomical observations. Satellites will be brighter then 99\% of the present objects in orbit. In this article, we shall discuss the challenges posed to observatories by the exponential growth in satellite constellations and steps being taken to engage with the parties involved to (partially) solve these issues and the efforts being made to mitigate these effects. We shall also introduce the proposed activities of the recently setup IAU Centre for the Protection of the Dark and Quiet Skies from Satellite Constellation Interference and at Educating observers at all levels internationally to deal with this new urgent crisis.

KEYWORDS Megaconstellations, Dark Skies, Satellites, Education

FM 2

#2174

Optical and NIR magnitude measurements of low Earth orbit satellites, from a global observing network

Jeremy Tregloan-Reed[1], Jorge Anais[2], Anh Duong-Tuan[3], Lizxandra Flores-Rivera[4], Pablo García[5], Rodrigo González[6], Maximilian Häberle[4], Boris Haeussler[6], Tobias Hinse[7], Edo Ibar[8], Uffe G. Jørgensen[9], Kim Yonggi[10], Kim Haeun[11], Valeska Molina[2], Theodoros Nakos[12], Edgar Ortiz[2], Ángel Otarola[6], Maria Romero-Colmenares[1], Pedro Sanhueza[13], Jesper Skottfelt[14], Mario Soto[1], Eduardo Unda-Sanzana[2], Joh-Na Yoon[10]

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Chile is disproportionately affected by the impact of LEO mega-constellation communication satellites due to the high concentration of the world's leading observatories and pristine dark sky conditions of the Atacama desert. Therefore, the protection of the dark and quiet sky is a priority not only for the astronomical community and Chilean people, but for future telescopes and observatories, such as the Vera Rubin, ESO ELT, and GMTO which will play a critical role in furthering our knowledge and understanding of the cosmos. We present results of the first year of observations of Starlink and Oneweb LEO satellites from telescopes based in Chile, Spain, Vietnam, and South Korea. With over 1500 successful observations to date, covering the optical (360 to 880 nm) and NIR (J, H, K), we can for the first time, begin to study in detail, the wavelength dependent phase curves of different satellite designs, whilst obtaining the stationary magnitudes. In addition the observations are allowing the accuracy of the satellite two-line elements to be measured as a function of time, helping to improve LEO satellite forecasting models, and so aid in the development of LEO satellite avoidance algorithms.

KEYWORDS light pollution, methods: observational, techniques: photometric

FM 2

#1343

Observations, analysis and characterization of satellites in Low Earth Orbit mega-constellations

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Several hundreds of satellites have been deployed in Low Earth Orbit (LEO) intended to facilitate worldwide ethernet access communications, and several tens of thousands are planned for deployment in the upcoming years by different international private companies. The sheer number of these kind of satellites together with their relatively low orbital heights and their ability to reflect sunlight have started to impact astronomical observations. The impact is larger, at least when considering the number of science images impacted by satellite streaks, for telescopes and instruments of large etendue and telescopes equipped with highly sensitive cameras and/or spectrographs. The brighter the satellites are, and the larger number of them, increases the chance for the mega constellations of LEO satellites to adversely affect astronomical science from ground-based observatories. Besides, if bright within the naked eye limit, this will change the way people may enjoy of the natural brightness of the night sky in their cultures. Here, we report of results from multi spectral bands observations of satellites, as well as, on the increased detection of satellite streaks in science images in large and small field-of-view survey telescopes. Their relative brightness magnitude has been checked against recommendations from our community, intended to mitigate the adverse effects of these satellites on astronomical imaging. The results show that the satellites are still brighter than recommended. These results have been obtained from observational campaigns and archival images analysis, in collaborations with colleagues in Chile, USA and Europe.

KEYWORDS satellites, megaconstellations, starlink, brightness

FM 2

#975

Impact of LEO Megaconstellations on the Zwicky Transient Facility Survey Observations

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There is a growing concern about an impact of low-Earth-orbit (LEO) satellite constellations on ground-based astronomical observations, in particular, on wide-field surveys in the optical and infrared. The Zwicky Transient Facility (ZTF), thanks to the large field of view of its camera, provides an ideal setup to study the effects of LEO megaconstellations - such as SpaceX's Starlink - on astronomical surveys.

I will discuss what can be learnt about satellite megaconstellations and their impact on wide-field surveys from the study of archival images collected by ZTF.

KEYWORDS light pollution, Starlink

FM 2

#2890

Impacts to U.S. Ground-based Astronomical Facilities

Bevin Vanderley[1]

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The proliferation of satellites poses new challenges to ground-based astronomical facilities. We present the results of studies conducted to quantify the impact to optical-infrared telescopes and radio facilities. We will describe the U.S. regulations which require coordination agreements for satellite operators utilizing certain downlink frequencies. We will also present a series of coordinated radio frequency (RF) measurement tests undertaken at NSF radio astronomy facilities with a satellite operator, including downlinks and the impact of user terminals on both interferometric and single-dish observations.

KEYWORDS spectrum management, radio, satellites, instrumentation

FM 2

#714

The brightness and colors of Oneweb satellites

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OneWeb is a new megaconstellation currently launching satellites. It differs from Starlink in the crucial aspect of operational orbit as well as the details of satellite design. The Starlink satellites orbit at about 350km altitude, but the OneWeb satellites orbit at 1200km. This makes them fainter in the optical, but they are visible to higher elevations and for a much larger fraction of the night.

The OneWeb constellation has only recently started launching satellites and so its effects on astronomy have yet to be fully explored. Initial observations indicate that they have V band magnitudes of 7 to 8, but their variability with wavelength, with time and elevation have yet to be fully explored. We here report observations of OneWeb satellites in the optical in several different bands, to determine the wavelength dependence of their brightness (measures taken by Starlink, for example to reduce the brightness of their satellites are found to be less effective in redder bands), and to determine how their brightness varies with elevation and time of night.

Using simultaneous observations in Sloan griz filters with Muscat2 at Telecopio Carlos Sanchez (Teide Observatory), we found that Oneweb satellites are brighter in redder bands: g= 8.73 pm 0.04, r=7.78 pm 0.03, i=7.20 pm 0.03, z=6.97 pm 0.02 (elevation ~ 30º). This is also confirmed at higher elevations (usint the IAC80 telescope) where we found in average: g=9.70 pm 0.07 and r=7.73 pm 0.02. We will continue monitoring the brigthness of Oneweb satellites at different positions in its orbit to monitor how the brightness changes over the course of an orbit and time.

KEYWORDS

On the space debris component in meteoroid models

Svitlana Kolomiyets[1], Serhii Kundyukov[1], Iryna Kyrychenko[2]

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Currently, meteoroid models have a space debris component. Dark and quiet skies are needed by humanity in many ways. Since the emergence of the space industry, the prediction of meteoroid hazard for spacecraft has become relevant. Over time, debris from the spacecraft and satellites themselves became a problem. The global progress in the space industry cannot be stopped. At the same time, the development of humanity must be civilized and must be regulated by rules and standards. The first step in curbing unforeseen situations is to account for them. The presentation will discuss the difference between meteoroid and artificial environments and the corresponding hazard aspects. A review of the state of the art on the problem of space debris in meteor research is given.

KEYWORDS Meteoroid models, Space debris, Environment, Problem of space debris, Meteor research, Meteoroid hazard, Satellites

e-Posters

FM 2

#2947

Active Shutter as a New Universal Tool to Protect Astronomical Observations in the Optical Range from the Effects of Outdoor Lighting Systems and Bright LEO-Satellites

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The rapid growth of the number of satellites with the increasing influence of outdoor lighting to the sky light pollution are causing enormous damage to astronomy and creating a demand for new protection solutions for optical observations. Particularly, long exposure images are subject to both a higher risk of individual pixel saturation and accumulation of uneven background noise. The paper addresses the research, design, and test results of a set of mitigation tools based on the Active Shutter technology. The tests were carried out at the SAI Caucasus Observatory with the RC600 telescope. The approach demonstrated high efficiency in protecting CCD (Andor Ikon-L) images. An Active Shutter is designed to interrupt the exposure of a scientific camera without interrupting the integration mode of the camera's photosensor. The design and application of a leaf and rotating shutters is described. Two cases of light disturbance are analyzed and discussed:

1. Outdoor light protection requires replacing conventional light sources in the vicinity of the observatory with the pulsed LED sources. The parameters allowed the setup to be insensible to the human eye; the potential health effects are analyzed. The shutter mounted on the telescope is synchronized with the lights using GPS, allowed to reduce the CCD's lighting background level significantly.

2. Satellite protection utilizes the same shutter element but uses data from an auxiliary detector with a wide field of view that allows to detect objects as they approach the telescope's field of view. An independent parallel processing using Space Situational Awareness services (e.g., NORAD) allows predicting transit times a few hours in advance. The results showed good prediction accuracy; the brightness of detected satellites is at least 6 mag.

This paper aims to contribute to the future modernization of modern astronomical optical telescopes using described approaches to reduce the negative effects of artificial light pollution.

KEYWORDS Dark sky, LEO satellites, Outdoor lighting, Optical astronomy, Active shutter, Mid-exposure shuttering, Long exposure image

An International Dark Sky Place in Uruguay: the first steps

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We present the latest advances towards the goal of certifying the first international dark sky place in Uruguay. The chosen region is located in the province of Rocha, characterized by natural areas rich in biodiversity and skies with very low light pollution, where we have measured an averaged sky background brightness of around 21.7 magnitudes per square arc second. Together with a group of tourism entrepreneurs, university colleagues, teachers and other groups interested in the preservation of the night sky and the development of astronomical tourism, we have presented a project to the departmental authorities to regulate public lighting, future or present, in addition to monitor the brightness of the sky as part of a scientific project of the CURE astronomical observatory located in Rocha. We continue to raise awareness of the importance of avoiding or mitigating light pollution and teaching training courses in astronomical tourism. Our actions are not limited to this province, but we are extending them to the entire national territory through agreements with other institutions or collaborations with interested groups.

KEYWORDS dark, quiet, sky, Heritage, astronomical, natural, tourism

FM 2
#1651

How to Pass a Lighting Ordinance

Sally Oey[1]

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If your municipality does not have a lighting ordinance, why not set one up? Depending on where you live, it may not be as hard to do as you think. This poster will walk you through the steps needed to enact local legislation. We share our recent experience in Ann Arbor, Michigan, USA (population 120,000). Smaller townships and rural areas arguably have the greatest immediate vulnerability to new light pollution, but they also have smaller governments, promoting easier legislative change.

KEYWORDS light pollution, site testing

e-Talks

FM 2

#2622

Impact Prediction of Mega-constellation Satellites on Gravitational Wave Follow-up Observation Based on Virtual Simulation

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Along with the generalization and scale growth of the commercial satellite constellations, light pollution due to the reflection of sunlight from the great number of satellites has caused severe impacts on observational astronomy, which has led to widespread concern in the astronomic community. In the aim to protect the Dark and Quiet Sky, we want to analyze the impact of mega-constellation satellites on astronomical observation quantificationally and visually, taking the SpaceX Starlink as an example. In this paper, the prediction of satellite orbit and its brightness is realized by obtaining satellite orbit data and calculating satellite visibility by using virtual simulation technology. The time and space stimulation function of the Worldwide Telescope is applied to simulate gravitational wave follow-up observation, which is disturbed rather greatly by the satellites, providing references for avoiding interference and optimizing follow-up observation planning. Though the paper focused on the follow-up observation of gravitational waves, our research outcome could be applied to a much wider range of astronomical observations.

KEYWORDS mega-constellation satellites, dark and quiet sky protection, virtual simulation, gravitational wave follow-up observation

FM 2

#1412

Dark Sky without Borders: Besides Astronomers, How to Interact and Build Consensus with Stakeholders from Other Disciplines?

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One People, One Sky. As an astronomy educator and popular science communicator, stargazing and night-sky observation are always important to conduct research on how we understand the stars and constellations in our night sky. However, we might be easily overlooked the importance of dark sky protection, and the seriousness of urban light pollution. It may not only affect the astronomical research, sidewalk astronomy, and remote observatory, but it could also disrupt the life cycle of natural wildlife, sustainability issues on energy wastes, and health status on sleeping quality. It is, therefore, crucial to have an overview of innovative approaches to setting up night sky brightness monitoring systems and promoting the awareness of dark-sky protection. This presentation will also share my experience, as an international committee of International Dark-Sky Association and IAU Dark Skies Ambassador, on the advocacy of public engagement and science communication through online.

KEYWORDS Dark SKy, sustainability, light pollution, public engagement, science communication

FM 3

Consensus Cosmic Shear in the 2020s

Invited & Contributed Talks

FM 3

#575

Cosmic Shear Analyses with KiDS: past, present and future

Marika Asgari[1]

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The Kilo Degree Survey (KiDS) is a purpose-built gravitational lensing survey with high quality images and a wide photometric coverage, resulting in very high fidelity data. Weak gravitational lensing is a powerful probe of the large scale structures in the Universe. Studying these structures allows us to understand the underlying cosmological model and constrain its parameters.

In this talk I will give and overview of the cosmic shear analysis of KiDS data, its past, present and future. I will then focus on the latest results from the weak gravitational lensing analysis of 1000 square degrees of data. Adopting the standard cosmological model (flat Lambda-CDM) we obtain results that are in 3 sigma tension with the cosmic microwave background (CMB) analysis of the Planck data in the estimates of the structure growth parameter, S_8 = sigma_8 (Ω_m/0.3)^0.5. I will show that our analysis is robust to a number of measurement and modelling systematics. Finally I will focus on constraints on a selection of alternative models and discuss the implications of the observed tension.

KEYWORDS Cosmic shear, Gravitational lensing, Observational cosmology, Tension, Large Scale Structures

FM 3

#3122

Cosmology from DES Y3 weak lensing

Alexandra Amon[1]

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I will present the cosmological weak lensing results from the Dark Energy Survey (DES) using its first three years of data taken using the Dark Energy Camera on the 4m Blanco telescope at CTIO. This analysis spans the full DES footprint, more than 4000 sq. deg. of sky, with the final shear catalogue containing more than 100 million galaxies in riz photometric bands, constituting the most powerful weak lensing dataset to date. The comparison of DES cosmological constraints on dark matter and dark energy from WL and LSS in the low-redshift Universe to CMB constraints provides an unprecedented test of the standard cosmological model, across high and low redshift. I will mention the main challenges that our analysis is susceptible to, and the summarise the approach to account for these and deliver robust cosmological constraints. Finally, I'll summarise new developments necessary to exploit future datasets.

KEYWORDS

Weak Lensing Cosmology from Subaru Hyper Supreme-Cam Survey

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The accelerating expansion of the universe is one of the most mysterious phenomena. The cosmic acceleration implies the existence of dark energy or the breakdown of Einstein's general relativity. Either way, revealing the source of cosmic acceleration can result in a paradigm shift in the field of modern physics. Weak gravitational lensing is a small, coherent distortion of distant galaxy images due to gravitational potential, which allows the direct measurement of dark matter spatial distribution. Weak lensing is one of the most powerful cosmological probes because of its capability to measure the nature of cosmic acceleration through the evolution of the large-scale structure of the universe. Hyper Suprime-Cam (HSC), a newly developed prime focus camera at Subaru Telescope, started a wide, deep galaxy imaging survey in 2014, covering 1,400 sq. degrees of the sky down to the i-band limiting magnitude of 26. The wide field of view, light-gathering power, and superb image quality of HSC make it possible to measure the weak lensing distortion with unprecedented precision. In this talk, I will present weak lensing cosmology results from the Subaru Hyper Suprime-Cam Survey first-year data, including the overview of the HSC instrument, construction of galaxy shape catalog for weak lensing measurement, and cosmological constraints from cosmic shear and the combination of galaxy-galaxy lensing and clustering. I will also present the prospect of HSC third-year cosmology analyses.

KEYWORDS

FM 3

#2779

Weak Lensing analysis of the 3,600deg2 of the CFIS-UNIONS data

Axel Guinot[1]

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UNIONS (Ultraviolet Near-Infrared Optical Northern Survey) is a survey that aims to cover 5,000deg2 in the Northern sky in 5 optical bands. It is the result of the collaboration of 3 Hawaiian telescopes: CFHT (r- and u-bands CFIS), HSC (g-band WHIGS, z-band WISHES) and Pan-Starr (z-band PS). Due to the location of these surveys, the r-band data reach an excellent sky quality (seeing ~0.65 arcsec) and a depth of 25 mag in the r-band. The combination of a large coverage, excellent image quality and multi-band data make UNIONS perfectly suited for weak lensing analysis. In this talk I will present the processing carried on the 3,600deg2 that has been observed so far. The data analysis has been done using two independent pipelines ShapePipe (Guinot et al, 2022) and LensFit. We have always valued the importance of having two pipelines to ensure the robustness of our results. I will demonstrate the quality of our catalogues through thorough validation tests and comparison between the two pipelines. We quantify our systematics from the PSF model to the galaxy's shapes. The two catalogues present a very low level of systematics: additive bias below 10-4, PSF leakage <1% and B-modes consistent with 0. The processed catalogues contain around 100 million galaxies which makes UNIONS one of the largest weak lensing surveys to date. Finally, I will end the presentation with preliminary science results obtained with the derived shear catalogues. I will present the results of a cluster lensing analysis and a peak count analysis both done using UNIONS data. Furthermore, the size of this survey enables new science such as trough lensing for which I will present preliminary results with a significant detection.

KEYWORDS cosmology, weak lensing, data processing, systematics

Cosmic shear reanalysis of KiDS-1000 with metacalibration shape catalog

Mijin Yoon[1]

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A new shape measurement and shear calibration pipeline in the Kilo-Degree Survey (KiDS) Collaboration has been developed based on metacalibration methodology, stacked observation images, and new KiDS-like simulation (SKiLLS: SURFS-Shark-based KiDS-Legacy-Like Simulations). We demonstrate the fidelity of the new pipeline by keeping calibration parameters under control while adding more complexity in our simulation setting from the simplest setting to the most realistic simulations. With the newly developed pipeline, we produce a new shape catalog of the KiDS-1000 data and conduct cosmic shear analysis to investigate its impact on cosmological constraints. The cosmological results are consistent with the previous results from the Lensfit catalog, which proves the robustness of both shape pipelines. The new metacalibration pipeline will be one of the official pipelines for the upcoming KiDS Legacy Data Release along with the Lensfit pipeline.

KEYWORDS Metacalibration, Kilo-Degree Survey, Cosmic shear, Cosmology, Shear calibration

FM 3

#1639

Forecasting gains in (4-6)x2pt large-scale structure analyses with spectroscopic-photometric galaxy cross-correlations

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We explore the potential for improved self-calibration of photometric galaxy sample redshift distributions through the joint analysis of up to six individual two-point functions: the 'classic' 3x2pt, comprised of photometric shear, spectroscopic clustering, and spectroscopic-photometric galaxy-galaxy lensing, plus the spec-phot cross-clustering (#4), the photometric GGL (#5), and the photometric auto-clustering (#6). We develop an analysis framework for the fast computation of 6x2pt theoretical angular power spectra under two scenarios of modelling for n(z) uncertainty: (i) un/correlated bin-wise shifts in the means of redshift distributions, and (ii) the more complex Gaussian-mixture redshift 'comb' model of Stolzner et al. (2020). We perform full simulated likelihood forecasts of the cosmological constraints expected from (3-6)x2pt analyses, employing perturbed photometric redshift distributions. The accuracy and precision of inference for key cosmological parameters are used as metrics for success, as we assess (i) the capacity for spec-phot cross-correlations, with/out the Gaussian comb, to calibrate-out errors in n(z) estimation, as well as the biases evoked by neglecting to re-calibrate, (ii) the impact of additional probes upon parameter inference, and (iii) how powerful a fully-fledged 6x2pt analysis is expected to be.

KEYWORDS weak lensing, photo-z self-calibration, forecasting, combined probes, data analysis

Can beyond ΛCDM models address the S8 tension? Extended cosmology analysis of the Kilo-Degree Survey

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Recent cosmic shear analyses have found a lower amplitude of clustering of matter than analyses of the cosmic microwave background (CMB) by Planck: the so-called S8-tension. If observational and astrophysical systematics can be ruled out, the question arises if the flat ΛCDM model is too restrictive and whether extensions to it can resolve these discrepancies.

In this talk, I will present analyses of cosmic shear from the Kilo-Degree Survey (KiDS-1000) with models beyond flat ΛCDM. We consider models where the sum of the masses of the neutrinos is allowed to vary, consider spatially curved Universes, vary the dark energy equation of state, and f(R) modified gravity. The S8-tension is found to disappear when allowing the dark energy equation of state to vary but the tension over the full shared parameter space with Planck remains at ~2σ in this wCDM model. Finally, I will show that neither jointly analysing cosmic shear with galaxy clustering, super novae, or CMB lensing, nor fixing a subset of parameters to the Planck best-fit values resolves the S8-tension.

KEYWORDS Cosmology, Cosmic shear, Tensions, Extended models

FM 3

#1867

CMB tensions and systematics

Renee Hlozek[1]

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Cosmic shear consensus in the coming decade will depend on understanding the systematics in lensing shear measurements across different surveys, and placing them in context with other measurements of cosmological parameters. I will present a review of Cosmic Microwave Background systematics and the tensions in the cosmological parameters between CMB measurements and other probes. I will discuss these systematics in the context of future planned CMB missions.

KEYWORDS CMB, observations, systematics, tensions

FM 3
#577

Tensions in Cosmology: H0 measurements

Sherry Suyu[1]

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The Hubble constant (H0) is a key parameter in cosmology that sets the expansion rate of the Universe. Independent determinations of H0 are important to ascertain the possible need of new physics beyond the standard cosmological model, given the tension in current H0 measurements. I will present the latest H0 measurements especially from strong lensing with time delays, and discuss avenues toward precise and accurate H0 determinations from lensing time delays. I will show the bright prospects of gravitational lens time delays as an independent and competitive cosmological probe.

KEYWORDS strong gravitational lensing, cosmology

FM 3

#2915

Higher-Order Statistics with Stage IV surveys

Jia Liu[1]

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While two-point statistics, i.e., two-point correlation function and power spectrum, have been the default method in analyzing weak lensing data to date, they are inadequate in extracting all the information expected from upcoming State-IV surveys that probe deep into the small, nonlinear scales, such as the Vera Rubin Observatory Legacy Survey of Space and Time (LSST), Euclid Space Mission, and the Nancy Grace Roman Space Telescope. Weak lensing higher-order (non-Gaussian) statistics are expected to unveil new cosmological and astrophysical information and enable us to calibrate systematic effects. I will present recent works that aim to optimize Stage-IV weak lensing analysis, with a focus on methods beyond the two-point statistics.

KEYWORDS higher order statistics, non-gaussian, weak lensing, lsst

FM 3
#623

On the road to percent accuracy: The Reaction Way

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Tapping into the unprecedented statistical power of upcoming cosmic shear surveys will require exquisite knowledge of the matter power spectrum over a wide range of scales. Fully analytical methods can achieve such precision only in the quasi-linear regime of structure formation. For smaller non-linear scales we must rely on N-body and hydrodynamical simulations, which in spite of technological advances and improved algorithms remain computationally expensive. By training on a limited number of simulated cosmologies, emulators can achieve competitive accuracies with calculations taking a mere fraction of a second. However, after appreciating the finitude of the available resources we soon come to the realisation that these techniques will be able to produce predictions only for a restricted sub-set of extensions to the “vanilla” ΛCDM cosmology. Moreover, if we believe that the observed tensions between late- and early-time cosmological probes is the result of new physics, it is very much possible that the true cosmology falls outside this class of models for which we have emulators.

I will present a promising method that draws strength from the combination of halo model, perturbation theory and emulators—the reaction framework. I will show how a power spectrum evolved in the standard cosmology can be readily adjusted to account for physics beyond ΛCDM, and discuss the accuracy of the reaction for well-known modifications to gravity, dark energy parametrizations and massive neutrinos.

KEYWORDS cosmology, large-scale structure, theory, methods

FM 3
#820

Cosmic shear from Einstein rings

Pierre Fleury[1]

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To date, cosmic shear measurements are exclusively performed from the observation of galaxy ellipticities. In this talk, I will introduce a new technique based on the distortions of strong-lensing images - notably Einstein rings - which are able to probe the line-of-sight shear produced by the large-scale structure. Theoretical arguments will be followed by a proof of concept based on mock images generated with the lenstronomy software. This novel way of probing comic shear promises exciting synergies between weak and strong lensing observations, e.g. within the Euclid survey.

KEYWORDS Gravitational lensing, Weak lensing, Strong lensing, Cosmic shear, Einstein rings, Line-of-sight effects, Lenstronomy

FM 3

#561

Weak-lensing Mass Reconstruction of Galaxy Clusters with a Convolutional Neural Network

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We introduce a novel method for reconstructing the projected matter distributions of galaxy clusters with weaklensing (WL) data based on a convolutional neural network (CNN). Training data sets are generated with ray-tracing through cosmological simulations. We control the noise level of the galaxy shear catalog such that it mimics the typical properties of the existing ground-based WL observations of galaxy clusters. We find that the mass reconstruction by our multilayered CNN with the architecture of alternating convolution and trans-convolution filters significantly outperforms the traditional reconstruction methods. The CNN method provides better pixel-to-pixel correlations with the truth, restores more accurate positions of the mass peaks, and more efficiently suppresses artifacts near the field edges. In addition, the CNN mass reconstruction lifts the mass-sheet degeneracy when applied to our projected cluster mass estimation from sufficiently large fields. This implies that this CNN algorithm can be used to measure the cluster masses in a model-independent way for future wide-field WL surveys.

KEYWORDS weak lensing, dark matter, galaxy clusters, artificial intelligence

FM 3

#698

NIRWL: Identifying Systematics in Near-infrared Weak-lensing Measurements with CANDELS/HST

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[2]Korea Astronomy and Space Science Institute, Korea Astronomy and Space Science Institute, Republic of Korea

Upcoming weak-lensing surveys with telescopes such as Euclid, Rubin, and Roman will measure the properties of the universe with unprecedented statistical precision. In parallel with the increased precision is a requirement for comparable advances in systematics control. We have undertaken a Near-IR Weak-Lensing (NIRWL) study of the CANDELS/HST fields as a testbed for the future surveys. Utilizing the wide fields of CANDELS, we are exploring the impact of observed systematic effects of near-IR detectors on weak lensing. The lessons learned from our weak-lensing study will be critical for future weak-lensing surveys. Our careful modeling of the HST near-IR PSF has shown that IR weak lensing will have considerable systematic biases that must be corrected for. We will discuss the systematic effects and their significance for weak-lensing measurements. We will highlight the importance of sampling and discuss the bias that undersampling will imprint on Euclid and Roman observations.

KEYWORDS weak lensing, infrared surveys, infrared systematics

FM 3
#1574

COSMOPOWER: Deep Learning – accelerated cosmological inference from next-generation surveys

Alessio Spurio Mancini[1]

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Next-generation Large-Scale Structure (LSS) and Cosmic Microwave Background (CMB) surveys will provide us with unprecedented statistical power to assess the nature of the "tension" between LSS and CMB cosmological constraints. However, the computational challenges posed by the unprecedented size of these datasets dangerously hinder the feasibility of their analysis within a rigorous statistical framework for uncertainty propagation, such as the one provided by Bayesian inference. The plethora of contaminants affecting cosmic shear analyses, in particular, urgently calls for the development of sophisticated pipelines that can ensure a level of accuracy in the final cosmological constraints corresponding to the unprecedentedly high precision provided by these future datasets.

In my talk I will present COSMOPOWER, an open-source Python framework for Bayesian inference from next-generation CMB and LSS surveys. COSMOPOWER provides orders-of-magnitude acceleration to the inference pipeline by training Deep Learning emulators of matter and CMB power spectra. I will show how these emulators meet the accuracy requirements for application to both currently available cosmological data, such as from the Kilo-Degree Survey (KiDS), as well as to simulated, next-generation data from e.g. a Euclid-like survey. The emulators always recover the fiducial cosmological constraints, while providing a speed-up factor up to O(104) to the complete inference pipeline. Bayesian parameter contours can thus be recovered in just a few seconds on a common laptop, as opposed to the many hours, days or months of runtime on computer clusters required by standard methods. I will also show an application of COSMOPOWER to the latest cosmic shear data from KiDS to derive constraints on an interacting dark energy model. I will conclude with an outlook on extensions of COSMOPOWER that are currently being developed to solve long-standing problems in the analysis of current and future cosmological data, such as the effect of the Limber approximation on the computation of LSS power spectra.

KEYWORDS cosmology, machine learning, statistical methods, large-scale structure, cosmic microwave background

FM 3
#3124

Nancy Grace Roman Space Telescope

Christopher Hirata[1]

[1]Physics and Astronomy, The Ohio State University, United States of America

The Nancy Grace Roman Space Telescope will carry out a suite of observing programs in the near infrared, including a wide area imaging and spectroscopic survey of the extragalactic sky. I will give an overview of the Roman observatory; its weak lensing capabilities, including both the Reference Survey and examples of possible alternatives; and complementarity with the other facilities planned for the 2020s. I will highlight some of the ongoing work on how characteristics of the observatory, instrument, and detectors impact cosmic shear measurements.

KEYWORDS

Weak Lensing with the Rubin Observatory LSST

Francois Lanusse[1]

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With the start of full survey operations planned for early 2024, the Vera C. Rubin Observatory's Legacy Survey of Space and Time (LSST) will bring weak lensing firmly into the Stage IV era, with a ~18,000 sq. deg. ugrizy optical survey ultimately reaching a depth of i ~ 26.8 at the end of its 10 year observing period. The first year of LSST data alone is expected to surpass the constraining power of all current Stage III lensing surveys, and at the same time will already push the boundaries of state-of-the-art shear inference and cosmic shear modeling.

In this talk, I will present the timeline and status of the Rubin Observatory and LSST and review the plans of the LSST Dark Energy Science Collaboration (DESC) for conducting the weak-lensing analysis of LSST data, highlighting in particular the work going into robust shear estimation and preparation of end-to-end analysis pipelines.

KEYWORDS Weak Lensing, Stage IV Survey, Vera C. Rubin Observatory, Cosmic Shear

FM 3

#2394

Cosmic shear with the ESA/NASA Euclid space mission

Hendrik Hildebrandt[1]

[1]Astronomical Institute, Ruhr University Bochum, Germany

In this talk I will present the prospects of cosmic shear measurements with the ESA/NASA Euclid space mission scheduled to launch in 2023. I will review the mission design, technical requirements, and expected science results. In particular, I will show how the current work on precursor surveys and increasingly complex simulations drives the preparations for the mission. In combination with indispensable ground-based follow-up surveys, Euclid will yield the definitive cosmic shear measurement of the 2020s with the potential to solve the riddles of the physical nature of dark energy and possibly the persistent tension in S8.

KEYWORDS

FM 3

#462

Shear Measurement Strategy in CSST

Jun Zhang[1]

[1]Astronomy, Shanghai Jiao Tong University, China

After giving a brief introduction of the China Space Station Telescope, I will talk about its strategy for shear measurement. Using simulations and existing data sets, I will demonstrate how to overcome several known sources of systematic errors in shear measurement, including pixelation effect, selection effect, boundary effect, source-noise coupling effect, etc.. I will also talk about other aspects of data processing in CSST, including photo-z evaluation, synergy between Euclid and CSST.

KEYWORDS weak lensing, cosmology, shear, dark matter, dark energy, survey, galaxy

e-Posters

FM 3

#1802

Optimal all-sky power spectrum estimation techniques for upcoming Stage-IV weak lensing surveys

Alessandro Maraio[1]

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With upcoming Stage-IV weak gravitational lensing surveys, such as Euclid and Rubin LSST, expected to generate cosmic shear data to unprecedented levels of precision, we need to ensure that the compression of the data to two-point statistics is as optimal as possible. If it is not, this could induce additional errors in the final cosmological parameter constraints, which would detract from the ultimate constraining power of the underlying data.

This estimation of the power spectrum should be unbiased and have minimal errors, as both are essential quantities to ensure that our parameter constraints lead us to derive the correct physical interpretation of our universe from the data.

I will present results from a comparison of the standard power spectrum estimator (the Pseudo-Cl method), which is known to be suboptimal, with a new implementation of the optimal estimator (the Quadratic Maximum Likelihood estimator; QML). I will showcase the properties of our new novel estimator, demonstrating its clear advantages over existing QML methods and quantifying the improvements over the baseline methods currently being developed by Stage-IV surveys.

KEYWORDS Cosmic shear, Weak lensing, Cosmology, Power spectrum estimators, Optimal estimators, Parameter constraints, Euclid

FM 3

#1074

Polytropic dark matter fluid: An “Occam’s razor” approach to the dark energy concept

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In the last 25 years, a continuously growing list of observational data has verified the existence of a distributed energy component in the Universe, i.e., one that does not cluster at any scale. Reflecting our ignorance on its exact nature, this new constituent of the cosmic matter-energy content was dubbed dark energy (DE). The determination of DE’s exact nature has become one of the biggest problems in theoretical physics and cosmology; consequently, (too) many models have been proposed. Here, we review a series of recent theoretical results, regarding a conventional approach to the DE concept. In short, by compromising General Relativity and Thermodynamics at cosmological scales, we end up with a model without any extra energy component. In this model, the Universe is filled with a perfect fluid of self-interacting dark matter (DM), the volume elements of which perform polytropic flows. Consequently, the energy of this fluid’s internal motions should also be considered as a source of the universal gravitational field. As we demonstrate, this form of energy can compensate for the extra (dark) energy needed to compromise spatial flatness in an accelerating Universe. In this case, there is no disagreement between observations and the theoretical prediction of the (distant) supernovae Type Ia distribution. In fact, the cosmological model with matter content in the form of a polytropic-DM fluid can interpret to high accuracy any observational data associated with the recent history of Universe expansion, thus arising as a mighty contestant for a realistic DE model, i.e., a viable alternative to ΛCDM model.

KEYWORDS Accelerated expansion, Accelerating Universe, Dark energy, Dark matter, Polytropic flows

FM 4

UV Insights to Massive Stars and Young Stellar Clusters

Invited & Contributed Talks

FM 4

#625

Massive Stars in the far and extreme ultraviolet

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From the main sequence to their late evolutionary stages, massive stars spend most of their life as hot stars. Due to their high effective temperatures, the maximum of their emitted flux falls into the regime of ultraviolet wavelengths. Consequently, these stars emit a significant number of photons with energies sufficiently high enough to ionize hydrogen and potentially also other elements. As simple as these fundmental considerations are, as complex is a realistic estimate of the resulting ionizing fluxes, in particular for energies above 54 eV.

Estimating the ionizing flux budget of hot stars requires accurate models of their spectral energy distributions (SED), covering in particular the far and extreme ultraviolet region. Modern atmosphere models that incorporate the so-called line-blanketing effect, i.e. taking into account the millions of lines from iron and other elements, yield a complex picture here, illustrating that the SED of a hot, massive star often deviates significantly from a black body. The ubiquitous presence of stellar winds further complicates the picture as the absorption of photons to drive the mass outflow leads to additional flux being shifted to longer wavelengths, strongly affecting the flux budget at the highest energies.

On top of all these challenges, models estimating the ionizing fluxes of a whole population are facing the major challenge of properly estimating massive star formation and evolution, which contain major unsolved puzzles that are often interwoven with open questions on the stellar scale.

In this talk, I will give an overview of the ionizing impact of massive stars, ranging from the underlying concepts of modelling the SED over the influence of stellar winds up to the impact due to our uncertain picture of massive star evolution including additional candidates for He II ionizing flux sources due to products of binary evolution.

KEYWORDS Massive stars, ionizing flux, UV, stellar winds, stellar populations, outflows

FM 4

#849

X-Shooting ULLYSES

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Massive stars have strong stellar winds that direct their evolution through the upper Hertzsprung-Russell diagram, determine the black hole mass function, and set the amount of feedback such as the ionising flux as a function of metallicity Z. I will briefly discuss new developments in line-driven wind theory before discussing tests with the HST Director's spectroscopic UV project ULLYSES. Optimal extraction of key observables requires supplementary optical and infrared spectra obtained with XShooter on the VLT. I will therefore discuss the complemenatery aspects of these two large programmes in terms of wind physics, stellar evolution, and feedback.

KEYWORDS winds, mass loss, ultra-violet, ULLYSES, evolution, metallicity

FM 4

#386

Non-solar scaled abundances for massive stars: the chemical abundance breakthrough for galaxy evolution

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Our current understanding of galaxy evolution hinges on the assumption that the universe has Solar-scaled metallicity abundances, which is not applicable outside our Solar System. This prohibits progress in understanding how the distribution of the metals in stars are recycled into the interstellar gas of galaxies throughout cosmic time. I will present the first set of massive stellar evolutionary tracks, computed by modifying the Modules for Experiments in Stellar Astrophysics (MESA) 1D stellar evolution package, to fit the Galactic Concordance abundances for hot massive Main-Sequence stars. These models are based on observed metal abundances in HII regions using the Galactic Concordance scaling system, which allows us, for the first time, for us to accurately compare stellar observations against models that are not constrained solely against a single star, the Sun. The evolutionary tracks for our Galactic Concordance abundance scaling provide a more physically motivated approach than simple uniform abundance scaling with metallicity for the analysis of HII regions and have considerable implications in determining nebular emission lines and metallicity. We find that the ionising photon output differs by up to 2dex from Solar-scaled stars for ages up to 5 Myr, which has broad implications for our interpretation of emission line spectra from observations. As the surface enhancement of elements in massive rotating stars have broad impact on the ionizing spectra of high-redshift, low-metallicity galaxies, stellar models with realistic, variable metallicities need to be considered to accurately model and predict the properties of galaxies across cosmic time.

KEYWORDS massive stars, winds, chemical evolution

FM 4
#1501

Weakening the winds with the ULLYSES data set: examining the presence of a bi-stability jump

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Radiation-driven mass-loss is an important, but still highly debated, driver for the evolution of massive stars. Current massive star evolution models rely on the theoretical prediction that low luminosity massive stars experience a sudden increase in mass loss below a stellar effective temperature of about 20 000 K. This so-called bi-stability jump is thought to originate from the change in ionisation state of iron lines inside the wind. However, novel radiation-driven mass-loss rate predictions show no such bi-stability jump (Bjorklund et al. 2022). Instead, stellar mass loss decreases with decreasing stellar luminosity/temperature, which may potentially affect the post main-sequence evolution of massive stars differently than hitherto anticipated.

The ULLYSES data set provides a unique opportunity to investigate the theoretical bi-stability jump dichotomy and may help to assess the existence of the bi-stability jump in massive star winds. By utilising UV spectra from ULLYSES combined with X-shooter optical data it is possible to obtain empirical mass-loss rate constraints, that are no longer degenerate to the effects of wind clumping, and derive novel empirical constraints on the mass-loss behavior across the temperature range of the bi-stability jump.

In this talk, I will first present new line-driven theoretical models from Bjorkund et al. (2019, 2021,2022), which are developed in our research group at the KULeuven, and explain why these do not show any sign of a bi-stability-jump in mass loss. Additionally, I will show some first, tentative empirical results for stars around the bi-stability region, based on genetic algorithm fits of UV+optical ULLYSES data by means of the FASTWIND code. Empirical results will be compared to the new theoretical predictions, and the results will be discussed in the broader context of what the (potential absence of a) bi-stability jump means for massive-star evolution predictions.

KEYWORDS Massive stars, Mass Loss, bi-stability jump, ULLYSES, Stellar Winds

FM 4

#2990

Massive binaries and the UV connection

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In this short review, I will present present an overview of recent works in the field of massive stars, with an emphasis on their binary aspect. I will attempt to identify problems where the UV domain provide important diagnostics. I will cover progresses in the determination of massive stars multiplicity properties across the upper Hertzsprung Russell diagram, including properties of main-sequence and post-main sequence populations of massive stars. I will discuss results of ongoing campaigns to identify post-interaction binary candidates, outlining the challenges of the endeavor. I will also discuss the need for accurate stellar wind characterization to properly constrain CNO abundances, which is a key tracer of singe and binary star evolution. I will finally address the ongoing efforts in the community to identify massive OB binaries with helium star or with degenerate companions. Both types of systems, if properly characterized, are believed to provide important insights into binary evolution in an intermediate stage immediately preceding or immediately following the core-collapse of the initially most massive star. The identification of such systems have however been heavily debated in the literature.

KEYWORDS

New empirical mass-loss rates and wind properties of massive stars at low metallicity

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Hot, massive stars are known to host unstable, radiation-driven outflowing winds, giving rise to dense clumps of material which severely affect the diagnostic techniques used to derive wind properties of massive stars. Most of the current diagnostic models account for wind inhomogeneities by assuming a one-component medium consisting of optically thin clumps, and maintaining a smooth velocity-field. However, this neglects important light-leakage effects through porous channels in-between the clumps. We have recently incorporated these light-leakage effects into our stellar atmosphere modelling code FASTWIND, and here we will present quantitative mass-loss results from a combined Ultraviolet-Optical wind analysis of 40 O-stars across the Galaxy, LMC and SMC. Using a genetic-algorithm fitting-approach, we investigate the impact the wind physics has on derived stellar and wind parameters, and how this depends on metallicity and spectral type. These results also provide an excellent base to expand upon with upcoming large surveys, such as (XSH-)ULLYSES which will provide optical data to complement the (HST-)ULLYSES UV survey for a sample of 250 OB stars at low metallicity. By applying the method presented here to such a sample we will be able to establish trends between wind properties and fundamental stellar parameters on an unprecedented scale. As the ULLYSES UV spectra are already available, we will also present results for terminal wind speeds measured from saturated P-Cygni UV line profiles. These results, when combined with previous studies on Galactic samples, allow us to obtain new empirical estimates of the metallicity dependence of terminal wind speeds.

KEYWORDS massive stars, stellar winds, UV spectroscopy, stellar atmospheres, mass loss

FM 4

#1483

Mass-loss implementation and temperature evolution of very massive stars

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The extreme winds of Very massive stars (VMS) not only dominate the evolution of such objects by continuously losing mass throughout their lifetime, but also influence the physics of the surrounding medium due to their strong ionising and mechanical feedback. Already during the main-sequence (MS) that spans nearly 90% of the entire lifetime, VMS can lose a large fraction of their initial mass due to their extremely high luminosities. Despite the MS mass loss shaping the evolution of these objects and their final fates, we know very little regarding the properties of the winds in close proximity to the Eddington limit. Using the 1D stellar evolution code MESA we focus on the MS evolution of VMS with a new theoretically informed mass-loss recipe that naturally switches from a canonical optically-thin O-star wind to an enhanced optically-thick Wolf-Rayet (WR) type wind above a certain model-independent transition mass loss point. We find the VMS with initial mass greater than 200 Msun undergo chemically homogeneous evolution throughout the MS, with mass loss being the single-most important process deciding the fate of these stars. We find our VMS models to steeply drop in luminosity and evolve almost vertically in the Hertzsprung-Russel (HR) diagram at nearly constant Teff, that naturally explains the narrow range of VMS temperatures observed in both the Arches Cluster near the Galactic center and the 30 Dor region in the LMC. This distinct behavior of a steeply dropping luminosity is shown to have a self-regulatory effect that keeps temperatures constant during evolution in the HR-diagram. Our models are the first physically-motivated models for massive stars in the critical 100-300 Solar mass range that dominate the ionising flux and mechanical input into young clusters.

KEYWORDS Evolution, Massive stars, Mass loss, Winds

FM 4
#923

Very massive stars and very metal-poor stars: connected topics?

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'Very massive' and 'very metal-poor' are two extremes of the parameter space of massive stars that have a large impact on the production of ionizing photons. Based on IMF and radiation-driven winds arguments one would expect that the existence of very massive stars is linked to low metallicity. Yet, the most massive stars known in the nearby Universe are not located in the most metal-poor environments. I will discuss the evidence on very massive stars and what properties are to be expected from theoretical models. I will also review present and near-future work on very metal-poor massive stars with a critical view on what we will be able to learn from the overall sample. I will finish by opening a debate on whether or not it is realistic to establish a relation between very metal-poor with very massive stars or if additional parameters must come into play.

KEYWORDS Massive stars, UV, Low-metallicity

FM 4
#1067

Are Very Massive Stars truly needed to explain the extreme broad He II emission of NGC 3125-A1?

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Super star cluster A1 in starburst galaxy NGC 3152 shows broad He II stellar-wind emission lines at 4686 (optical) and 1640 (UV) \AA. The lines are among the strongest observed in the nearby Universe and cannot be reproduced with population synthesis models that use a conventional upper mass limit of the stellar Initial Mass Function, unless an unrealistically top-heavy IMF is adopted. A main interpretation of past observations is that the lines originate in the winds of Very Massive Stars (VMS), whose initial masses exceed ~100 Msun, like the ones dominating the ionizing and mechanical output of cluster R136 in the LMC. We present main results from the analysis of new, higher spectral resolution UV observations of NGC 3125-A1 that we use to: i) determine if there is a contribution from nebular emission to the He II UV line, ii) test recently-improved Charlot & Bruzual 2019 models that include VMSs, and iii) compare with observations of evolved massive stars from HST's "Ultraviolet Legacy Library of Young Stars as Essential Standards" (ULLYSES). We discuss the progress and limitations of the models, as well as whether VMSs are truly needed in light of ULLYSES recent observations.

KEYWORDS Very Massive Stars, Starburst, Star Clusters, Initial Mass Function, Population Synthesis Models, Ultraviolet, Star Forming Dwarf Galaxies

FM 4
#1804

The Ionizing Spectrum of an Extremely Metal-Poor O Star Powering an HII Region

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Metal-poor, star-forming dwarf galaxies power extreme nebular emission and likely played a major role in reionizing the universe at high redshift. Determining the astrophysics driving their ionizing photon production is essential to advance our understanding of cosmic reionization, but that endeavor is fundamentally limited by the lack of observations that can constrain the ionizing spectra of individual, metal-poor O stars. The nearby, extremely metal-poor galaxy Leo P (3% Z_sun) hosts just one O star that is powering a bright HII region. In Telford et al. (2021), we analyzed FUV spectroscopy of this O7-8 V star and showed that it is a fast rotator driving a weak stellar wind. These properties are expected to be common at low metallicity and imply higher ionizing flux than predicted by the standard, non-rotating stellar models that are typically used to interpret galaxy observations. In this talk, we present new Keck/KCWI optical integral field unit spectroscopy of the O star and HII region in Leo P. From these data, we measure nebular emission line fluxes and equivalent widths, complementing the unexpectedly strong detections of O III] and N III] lines in the FUV data. We fit photoionization models to the observed nebular lines of various ions, which encode the number of photons above different ionization energies, to infer the shape of the stellar ionizing spectrum. The combined power of FUV and optical spectra enables a unique test of stellar spectral models at the low metallicities relevant for modeling the contribution of early dwarf galaxies to cosmic reionization.

KEYWORDS

FM 4
#1340

Modeling the ionizing spectrum of local star-forming galaxies

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Local star-forming galaxies (SFGs) are thought to be close analogs to galaxies at high redshift. Due to their proximity, SGFs are ideal for studying the physical properties, stellar population, and nebular gas in much more detail. The COS Legacy Spectroscopy SurveY (CLASSY) comprises UV/COS plus optical spectra of 45 local SFGs selected to cover a wide range of physical properties. We use photoionization models in order to reproduce the UV and optical nebular emission linesl of the CLASSY sample. Our models include the stellar population fit derived from the UV continuum and observational properties such as metallicities, the N/O and C/O ratios, and ionization parameters. The goal of our models is to simultaneously reproduce the low, intermediate, and high ionization emission lines. In particular, we present preliminary results for those galaxies with high ionization features, such as He II λ4686 and [O IV] λλ1401,1407. The synergy between UV+optical allows constraining the nebular properties and young stellar population to model the emission line covering different ionization states of the gas. It will allow analyzing the processes required to interpret the high ionization features and explore the physical conditions present in high redshift galaxies.

KEYWORDS star-forming galaxies, photoionization models, UV, optical

FM 4

#893

Direct Constraints on the Massive Stars Underlying Strong High-Ionization Nebular Emission Locally

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The closest populations of young massive stars probing significantly below the metallicity of the SMC are a rare and precious resource for understanding metal-poor massive stars. With JWST and the ELTs poised to extend nebular spectroscopy to higher redshifts and lower stellar masses than previously accessible, testing the models necessary to understand them in nearby environments is particularly timely. In this talk I will discuss the results of directly modeling the stellar continuum in deep spectra of some of the most extreme systems known in the local Universe. The deepest FUV spectroscopy yet obtained for unresolved low-O/H dwarfs reveals strong evidence for the presence of extremely metal-poor (sub-10% solar) massive star populations in the galaxies powering the strongest nebular CIV locally. Detection of stellar photopheric features alongside the FUV stellar wind lines provides a unique opportunity to test prescriptions for extremely metal-poor stars at ages and masses inaccessible to resolved-star spectroscopy. In the system with the best-constrained FUV spectrum, this comparison reveals evidence for a systematic discrepancy between the model-predicted and observed CIV wind feature, suggestive of potential deficiencies in modeling the most luminous stars at these metallicities. Further progress in constraining modeling prescriptions will require work along several axes. I will describe results from modeling the FUV stellar continuum in the broader CLASSY survey, and new efforts to expand the population of known dwarf galaxies at very young effective ages and very low metallicities. Finally, if time allows I will present new results from several programs focused on resolved metal-poor massive stellar populations in the Local Group including some of the first FUV spectra of sub-SMC massive stars, which provide a complementary approach to many of the same crucial questions facing the star-forming galaxy modeling community.

KEYWORDS massive stars, ultraviolet spectroscopy, stellar winds, ionizing radiation

FM 4
#416

Observations of massive stars in extragalactic star clusters

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I will review ultraviolet (spectroscopic) observations of hot, luminous stars in extragalactic high mass star clusters, ranging from spatially resolved young star forming regions within nearby galaxies (e.g. R136 in the LMC, NGC346 in the SMC) to unresolved super star clusters beyond the Local Group, including exceptionally young regions in NGC3125 and NGC2366/Mrk 71. I will summarise what we can learn about unresolved young clusters from their most massive stars and vice versa.

KEYWORDS stars: massive, galaxies: star clusters, ultraviolet: stars, ultraviolet: galaxies

FM 4

#1024

Universal Upper Ends of the Stellar Initial Mass Function in the Young and Compact LEGUS clusters

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We investigate the variation in the upper end of stellar initial mass function (uIMF) in unresolved, young and compact stellar clusters in five nearby galaxies within ~5 Mpc. All the young stellar clusters (YSCs) in the sample have ages less than 4 Myr and masses above 500 $M_{\odot}$. The YSC catalogs were produced from Hubble Space Telescope images obtained as part of the Legacy ExtraGalactic UV Survey (LEGUS) Hubble treasury program. They are used here to test whether the uIMF is universal or changes as a function of the cluster's stellar mass. The method we employ for this test is to measure the Hα luminosity of the star clusters as a proxy for their ionizing photon rate, and chart its trend as a function of cluster mass. In doing so, we carefully account for stochastic sampling of the uIMF. The advantage of our approach relative to previous similar attempts is to use cluster catalogs that have been selected independently of the presence of Hα emission, thus removing a potential sample bias. We find that the uIMFs show no dependence on cluster mass, suggesting that the maximum stellar mass that can be produced in star clusters is universal, in agreement with previous findings.

KEYWORDS Nearby Galaxies, Star Clusters, Star Formation, Massive Stars, Initial Mass Function

FM 4

#978

Could kilomasers pinpoint supermassive stars?

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22.2 GHz water masers are generally associated with massive star formation. Recently, a very strong nuclear kilomaser, W1, has been found in a nearby galaxy (NGC 253) that is associated with a forming super star cluster. It has been proposed that kilomasers could arise from the accretion disc around supermassive stars (>1000 Msun). Such hypothetical stars are proposed candidates for polluters responsible for the chemical peculiarities in the globular clusters, i.e. large variations in light elements; the main one being O-Na, C-N and Mg-Al anticorrelations. Additionally most of the globular clusters demonstrate multiple sequences in the colour-magnitude diagram, proving that they host multiple stellar populations. It has been suggested that the second population forms from the hot-hydrogen burning yields of the first population via self-enrichment. At the present time it is very hard to observe supermassive stars due to their location. The candidate forming massive clusters are located outside the Milky Way with very dense centers, where the hypothetical star would be obscured by gas and dust. The supermassive stars would form via runaways collisions, simultaneously with the cluster, hence their disc is perturbed by stellar flybys, inspiralling and colliding stars. This raises the question if an accretion disc would at all be able to survive in such a dynamic environment and mase water lines.

We investigated what the predicted MASER spectrum of such a disc would look like using 2D hydrodynamic simulations and compared this to the W1 kilomaser in NGC 253. We derived model maser spectra from the simulations by using a general maser model for appropriate disc temperatures against velocity along the line of sight. All our our model discs survived. The model maser spectra for the most destructive case for the simulations of M = 1000 Msun are a good match with W1 kilomaser spectrum in terms of scaling, flux values and some of the signal trends. For the more massive star of 10,000 Msun the spectra start to resemble megamasers from AGNs rather than stellar masers. Our investigations thus support the hypothesis that kilomasers could pinpoint supermassive stars.

KEYWORDS maser, supermassive star, globular cluster, accretion disc, hydrodynamics

Clues to massive star clusters as engines of galaxy evolution

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The CLusters in the Uv as EngineS (CLUES) survey is a Cosmic Origins Spectrograph (COS) campaign aimed to acquire the 1130 to 1770 Å (FUV) rest frame of very young (<20 Myr) and massive (>104 solar masses) star clusters in galaxies that are part of the Hubble treasury program Legacy Extragalactic UV survey (LEGUS).

I will present the physical properties of the 20 young star clusters of the CLUES survey and report their physical properties as derived by both multi-wavelength HST photometry and FUV spectroscopy. Thanks to the synergy of the two different methods we can build a coherent picture of the diverse stellar populations found for each star-forming region (with sizes of 40 to 160 pc across). I will discuss the derived properties: age, mass, extinction, metallicity of the stellar populations as well as rate of ionising photons, mechanical energy and power released by SN explosions and stellar winds. The wealth of information included in the FUV spectroscopy of the CLUES survey includes the kinematics and column density of the outflowing gas clouds along the line of sight of the clusters, as probed by the ISM absorption lines. We detected outflowing clouds of both neutral and ionised gas with velocities of a few hundreds km/s up to 1200 km/s.

I will conclude with an overview of the additional scientific projects that are ongoing within the CLUES collaboration. CLUES will be a fundamental reference sample for the upcoming JWST and ELT FUV-restframe spectroscopy of resolved star-forming clumps in galaxies at redshifts beyond the peak of the comic star formation history.

KEYWORDS Ultraviolet surveys, Young star clusters, Stellar feedback, ISM

FM 4

#1749

The stellar content of UCHII regions: the molecular cloud GRSMC 045.49+00.04

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Ultra-compact HII regions (UCHIIs) mark the birth sites of massive stars. UCHIIs are ideal laboratories for studying the influence of young massive stars on their environment and the star-formation process. Previous studies have shown that UCHIIs do not necessarily form around a single young massive star, but that they may host a whole stellar cluster. Our target is the molecular cloud G045.49+00.04 at a distance of about 8 kpc. The main objective is to characterize the embedded young stellar objects (mass, evolutionary age and age spread, spatial distribution, luminosity function), more specifically in the UCHII regions G45.45+0.06, G45.47+0.05, and G45.48+0.13. We identified and classified the young stellar objects (YSOs) of the molecular cloud using near-, mid-, and far-infrared photometric data. A spectral energy distribution (SED) fitting tool, based on radiative transfer models, was used to determine the main parameters of the YSOs. Totally, in G045.49+00.04 we identified 1846 YSOs. The density distribution of the identified YSOs shows the presence of dense clusters in the UCHII regions, which contain about 300 YSOs. The clusters include a significant number of high- and intermediate-mass stellar objects, as well as younger YSOs with Class I evolutionary stage. The cluster members are distributed according to the shape of the cloud in far-infrared images. In general, the YSOs in these clusters have an evolutionary age larger than 106 years with an age spread of a few Myr. The small age spread suggests that the clusters may originate from a single triggering event. We suggest that the supernova explosion of the primary star in the high-mass X-ray binary (HMXB) GRS 1915+105 was the trigger. GRS 1915+105 HMXB is located at a distance of about 8 kpc from the Sun and the distance between the HMXB and the clusters is about 30 pc. We note that the presented work is part of a larger project to study both the stellar population and the interstellar medium in the GRSMC45.46+0.05 molecular cloud as a whole. Such a study is of great importance for understanding the formation and evolution of massive stars, and their impact on the environment, and the star formation process at large.

KEYWORDS Stars: pre-main sequence, Stars: luminosity function, Infrared: star, radiative transfer

FM 4
#633

STARS AND GAS IN CLUSTERS: FEEDBACK, EFFICIENCY AND EMERGENCE

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Star clusters are born hidden by huge extinction in Giant Molecular Clouds. Very quickly–usually in less than 5 Myr–the young stars disperse the remnant gas, star formation stops, and the cluster emerges and is seen at visible and UV wavelengths The eventual fate of the cluster depends on how the young stars interact with the gas and especially on the efficiency with which the gas is turned into stars. Stellar winds can combine to form cluster super-winds that clear away the gas (negative feedback) or that stall inside the cluster to create a second generation of stars from enriched material (positive feedback). We review recent observations and models of young Galactic and extra-Galactic clusters that are embedded and accreting gas, embedded but not accreting, and emerging, and discuss the dispersal processes they display. The effects of feedback can be understood in terms of the cluster compactness or M/R; the most compact and tightly bound systems, which may be proto-globulars, are seen today only in high pressure regions of starbursts.

KEYWORDS star clusters, star formation, molecular gas, winds

FM 4

#1848

How ionizing radiation escapes from compact star-forming regions in the Sunburst galaxy

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The escape mechanism of ionizing (Lyman-continuum) radiation from young star-forming galaxies is crucial to understanding how the Universe was reionized. We investigate the characteristics of a compact star-forming complex with leaking LyC radiation in the gravitationally lensed Sunburst galaxy at redshift 2.4. This galaxy provides unique opportunities to examine the physics of LyC escape down to tens of parsecs through a combination of Hubble Space Telescope's clean imaging (high angular resolution) and the zoom-in of lensing effect. We measure the key physical parameters of the leaking complex including UV-continuum slope, Lyman-alpha emission, Balmer line, and oxygen ([O III] and [O II]) line ratio based on narrowband HST images. Remarkably, we find very blue UV slopes (< -2.5) in the multiply magnified regions of the leaking complex, which is bluer than typical of star-forming galaxies as well as non-leaking regions in the galaxy. Moreover, there are significant correlations between the physical parameters of the leaking complex, such that bluer UV slopes are related to higher Ly-alpha escape fraction and oxygen line ratio. Our findings would suggest that highly ionized, compact star-forming regions with little dust promote the escape of LyC radiation in a galaxy.

KEYWORDS galaxies, star formation, galaxy formation, galaxy evolution, star clusters, emission-line galaxies

FM 4

#499

Lyman Continuum-Driven Superwind in Green Pea Analog Mrk 71

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The giant HII region Mrk 71 drives the extreme properties that make its host galaxy NGC 2366 a local Green Pea analog, providing unique insight on Lyman continuum escape. It is dominated by Knot A – a young, high-ionization, metal-poor super star cluster that is a strong candidate Lyman continuum (LyC) emitter (LCE). Broad, but faint, emission line wings tracing > 3000 km/s gas have been observed in Mrk 71, hinting that unusual forms of feedback may be at play in some LCE candidates. We analyze spatially-resolved emission line profiles of [OIII] and Hα, obtained with GMOS-N IFU, and find that the broad wings a) originate in Knot A and propagate out to > 200 pc; b) exhibit the kinematic structure of a wind; c) have symmetric, power-law line profiles; and d) cannot be explained by supernovae or stellar winds. On the other hand, analysis of the ionization parameter, stellar surface density observed in Knot A, and radiation pressure signals that feedback is radiation-dominated. We show that a clumpy, LyC and/or Lyα-driven superwind from Knot A can reproduce the observed broad wings. Our finding thus strongly suggests that LyC escapes from Knot A, which may also occur in other Green Pea LCE candidates. Indeed, we observe broad power-law wings in some LCE Green Peas, suggesting that high-velocity, power-law wings may be a distinctive signature of radiation-driven winds, and could be indicative of LyC escape.

KEYWORDS Dwarf irregular galaxies, Starburst galaxies, HII regions, Lyman-alpha galaxies, Radiative transfer, Stellar feedback, Interstellar line emission

FM 4

#2177

OVI emission in the halos of z~0.25 star-forming galaxies

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We present results of ultraviolet imaging of four low-redshift (z~0.25) star-forming galaxies with the Hubble Space Telescope. Using synthetic narrowband imaging we image emission from warm (T~105.5K) gas in and around galaxies by isolating the UV doublet of OVI (1031,1037Å). Only one of the galaxies shows significant OVI emission, and we place upper limits on the surface brightness, μOVI<8x1017 erg s-1 cm2 Å-1arcsec-2(3σ) for the remaining three SFGs. Ultraviolet spectroscopy of the brightest star-forming regions of the galaxies shows the λ~1000Å continuum to be well-detected, and the OVI doublet lines are detected in absorption for each of the galaxies, showing unequivocally that the gas is present. We derive column densities of NOVI~1014.5cm-2 for the detected galaxies, and measured outflow velocities of the warm, coronal equal to 200-300 km s-1. Using the measured NOVI in combination with the surface brightness in emission, we measure (or constrain with limits) the physical density of electrons (ne<1.2 cm-3), and the column lengths of the O vi-bearing warm gas (DOVI<20pc). We compare these results with those from simulations and observations where circumgalactic OVI was detected in emission. Overall, we conclude that radiative cooling from the hot phase is brief, and a minor energetic drain on the winds from starburst galaxies. We discuss the physical properties of the starburst galaxies and under what conditions galaxies may be produce signi cant O vi emission.

KEYWORDS Circumgalactic Medium, Starburst Galaxies

Massive star feedback in the Magellanic Clouds and the tidal Bridge

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Massive stars have far-reaching feedback effects that alter the surrounding environment on local, global, and cosmic scales. Spectral analyses of massive stars with adequate stellar-atmosphere models are important to study massive star feedback in detail. In this talk, I present the recent UV and optical studies of metal-poor massive stars associated with large-scale ISM structures in the Magellanic Clouds and the tidal Magellanic Bridge. This includes stars with metallicities ranging from 1/2 to 1/20th of solar. We discuss ionizing fluxes as well as mechanical energy provided by massive stars at low metallicity and further compare them with the observed energetics of the ISM. The results provide clues on the leakage of ionizing photons and hot gas in the Magellanic Clouds. The talk connects the study of individual massive stars to the collective feedback from massive star populations and summarizes how the importance of different feedback mechanisms (radiation, wind, supernova) change with the physical conditions of the ISM.

KEYWORDS massive stars, spectroscopy, low metallicity, feedback

FM 4

#2523

Modeling young star cluster populations

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I will review the state of the art in modeling young star clusters using population synthesis. I will compare the predictions of models which include massive binary star evolution with single star models. The evolution of the most relevant spectral features in the UV and visible range will be discussed and its relevance for dating local and distant clusters or galaxies will be assessed. Comparisons with relevant existing observational data will be shown.

KEYWORDS young clusters, stellar populations, population synthesis, UV features, binary stars, distant galaxies, star forming galaxies

FM 4
#2567

Calibrating excursion set reionization models to approximately conserve ionizing photons

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It is crucial to obtain the astrophysical properties of galaxies during the Epoch of Reionization (EoR) to investigate the first billion years of the Universe. The excursion set reionization framework is widely used due to its speed and accuracy to simulate the reionization process. A Bayesian framework combined with the excursion set reionization model allows us to constrain the astrophysical properties, such as the star-formation efficiency, the escape fraction of the ionizing photons, and the minimum halo mass hosting star-forming galaxies. However, it is known that it does not conserve the photon number. We introduce an efficient, on-the-fly recipe to approximately account for photon conservation, implemented in the public code 21cmFAST. Using a flexible galaxy model shown to reproduce current high-z observables, we quantify the bias in the inferred reionization history and galaxy properties resulting from the non-conservation of ionizing photons. Then, using a mock 21-cm observation, we perform inference with and without correcting for ionizing photon conservation. We will show that biases in the inferred galaxy properties when ignoring photon conservation are modest. The notable exception is in the power-law scaling of the ionizing escape fraction with halo mass, which can be biased from the true value by ~ 2.4σ.

KEYWORDS reionization, high-redshift, intergalactic medium

FM 4

#3013

What lurks below the Lyman Limit? Unearthing the unseen ionizing continua of extragalactic massive star populations

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Interpreting the properties of star-forming galaxies requires the unseen: a detailed accounting of the production of ionizing photons by massive stars. Stellar population synthesis models describe these ionizing photons by incorporating stellar evolution and atmosphere models to estimate the photospheric conditions within massive star populations. However, observations have not yet constrained the production of ionizing photons uniformly across the representative metallicity range. Here, I present a comparison of the stellar population synthesis models and recent high-quality rest-frame far-ultraviolet observations of star-forming galaxies at multiple redshifts and over two orders of magnitude in metallicity. The stellar population models nicely match many of the observed stellar wind and photospheric features. These models constrain the abundance and age distributions within galaxies. However, the features corresponding to the most massive stars are still challenging to reproduce, suggesting required refinements of future stellar population models. Importantly, I find that the star formation history, or equivalently the mass function, strongly complicates the interpretation of extragalactic stellar populations. Finally, recent observations of galaxies that emit ionizing photons provide a novel opportunity to directly constrain the stellar ionizing continuum. These observations provide a novel road map with testable constraints for the next generations of massive star models.

KEYWORDS

Tracing Massive Star Populations with Neutral and Low-Ionization Gas

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The interplay between the gas and stars in galaxies is one of the most fundamental, yet unsettled, drivers of galaxy evolution. The rest-frame FUV absorption lines encode the ionizing spectra of massive stars and provide a previously unexplored link between the most massive stars and the adjacent gas. Using the FUV spectra (1050—1800 Å) of 45 nearby star-forming galaxies from the high-resolution CLASSY Treasury sample, we present the first combined analysis of a large suite of UV absorption lines (Lyβ, OI, SiII, CII, AlII, FeII) and their relation to the massive star properties across a wide range of galaxy masses, metallicities, star formation rates, ionization parameters, and densities. This establishes the most complete picture of neutral and low-ionization gas outflows among a diverse sample of star-forming galaxies, to-date. Our sample is uniquely situated to analyze the stellar physics behind these low-ionization lines, their connection with global galactic properties, and will provide a crucial test for stellar population synthesis models.

KEYWORDS

e-Posters

FM 4

#3317

On the connection between the O32 ratio and LyC escape from simulated star-forming clouds

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Identifying Lyman continuum (LyC) leaking galaxies is an important step towards understanding the reionization history of the Universe. However, measuring the escape fraction of LyC photons in high-$z$galaxies is a very challenging task. We examine whether the O32 ratio, defined as the ratio between [OIII]λ5007 and [OII] λ3727 lines, can be used as a proxy for f(LyC). To this end, we construct synthetic spectra by post-processing high-resolution, radiation-hydrodynamic simulations of giant molecular clouds (GMCs) with the photo-ionization code, cloudy. We then combine the results with a random forest machine learning algorithm to calculate emission line strengths at different evolutionary phases of the GMC.

KEYWORDS reionization, first stars, HII regions, radiative transfer, ISM, emission lines

On the properties of six cores in the λ Orionis cloud: How UV radiative feedback affect the star-forming activity?

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The UV radiation from massive stars is one of the important feedback processes. This process can affect the accretion onto the forming star and subsequent collapse or fragmentation of the cloud down to cores. In this context, we present preliminary results of 1.1 and 1.3 mm dust continuum and 12CO (J=2-1) line data obtained with the Submillimeter Array toward six cores harboring Class 0/I objects in the λ Orionis cloud. They are located in the bright rimmed clouds, which are exposed to the far-ultraviolet radiation field by the O-type star λ Ori. Compact dust continuum emission is observed for all the six cores. Among them, only one core G196.92-10.37 shows a signature of binarity with separation of 4000 AU. The numbers of singles and binaries in our sample are five and one, respectively and the derived multiplicity frequency (MF) is 0.17. This value is lower than those found in the binary surveys toward Class 0/I objects, possibly due to radiative feedback from the nearby massive star λ Ori. We also clearly detect bipolar molecular outflows toward all the six Class 0/I sources. For each outflow, we calculate the mass (Mflow), momentum (Pflow), kinetic energy (Eflow), mechanical luminosity (Lflow), and force (Fflow) assuming optically thin emission in LTE at an excitation temperature, Tex, of 30 K. The median values of calculated properties are similar to those obtained in other filamentary clouds (e.g., Orion A & B), which may suggest that the radiative feedback from the massive star does not impact the decrease in outflow properties and limiting accretion of protostars.

KEYWORDS stellar feedback, outflow, protostar

FM 4

#3001

Bridging Galaxy Evolution Across Cosmic Time With the CLASSY Survey

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Rest-frame far-ultraviolet (FUV) spectra are fundamental to our understanding of star-forming galaxies, providing a unique window on massive stellar populations, chemical evolution, feedback processes, and reionization. JWST will soon usher in a new era, pushing the FUV spectroscopic frontier beyond z=10. The success of such future endeavors hinges on a comprehensive understanding of the massive star populations and interstellar medium (ISM) gas conditions that power the observed FUV spectral features. We present the COS Legacy Archive Spectroscopic SurveY (CLASSY) Treasury as a powerful and promising solution. The CLASSY atlas is the first high-quality, high-resolution FUV spectral catalog of star-forming galaxies at z~0. The spectra contain a suite of emission and absorption lines that simultaneously characterize the massive stellar populations that populate metal-poor galaxies, the physical properties of large-scale outflows that regulate star formation, and the chemical abundance patterns of the gas and stars. The CLASSY sample is consistent with the z~0 mass-metallicity relationship, but is offset to higher star-formation rates by roughly 2 dex, similar to z~2 galaxies. This unique set of properties makes the CLASSY atlas the benchmark training set for studies of star-forming galaxies across cosmic time.

KEYWORDS galaxies: evolution, galaxies: high-redshift, ultraviolet: galaxies, surveys, galaxies: ISM, (galaxies:) intergalactic medium, atlases

Investigating the properties of star cluster complexes in the collisional ring galaxy Arp 147

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Collisional ring galaxies are peculiar objects that form through the collision between a small galaxy companion and the rotation axis of a larger disk galaxy. The intense nuclear starbursts happening in those peculiar systems trigger the formation of relatively young (10 - 100 Myr) and compact (> 10^5 Msol) star clusters commonly known as young massive clusters. YMCs are useful tools that help better understand star formation mechanisms in different galaxy environments.

In this pilot project, we probe the YMC population hosted by the collisional ring galaxy Arp 147 (or IC 298 at a luminosity distance of 135 Mpc) with the aim to investigate the effects of the host environment on the star cluster properties. This research work is relevant in a way that there are only a handful of YMC studies hosted by collisional ring galaxies to date.

After retrieving the HST/WFPC2 archival images at F450W, F606W and F814W filters, we ran SExtractor on the combined BI-image and recovered more than 300 potential YMC candidates. We then performed aperture photometry using IRAF/PHOT. Photometric calibration as well as source selection were performed to output the YMC final catalog. We then plotted the source Color Diagrams and Luminosity Functions. Preliminary results reveal that the clumps are mostly young with a mass range between 10^5 - 10^7 solar masses. Before properly interpreting our results, we however need to assess possible bias such as observational incompleteness and blending effects, especially that our target is 100 Mpc away. Besides these analyses, our future work will also consist of computing the ages and masses of the clumps, and also building the Cluster Mass Functions.

KEYWORDS YMC, CRG, host environment

FM 4

#2530

A new demarcation line in the BPT diagram from optical and infrared line emission ratios

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We use the updated version of the CLOUDY photoionization code and state of the art population synthesis models to compute optical and mid infrared line emission ratios that are used to trace a new demarcation line defining the region occupied by star forming galaxies in the BPT diagram. We explore the dependence of this line on various model parameters.

KEYWORDS mid infrared, line emission ratios, BPT diagram, star forming galaxies, diagnostic diagrams

FM 4
#2528

Toward analysis of UV integrated spectra with a full spectrum fitting tool

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As UV surveys of stellar clusters continue to expand in size and scope, tools to process these observations in bulk will become increasingly vital. In light of this, we present the latest version of the Analyzer of Spectra for Age Determination (ASAD_uv), a full spectrum fitting tool. Our primary goal for this updated version of the program is to offer robust measurements (i.e. age, reddening, metallicity, radial velocity) of UV integrated stellar spectra. Our tool provides extensive diagnostics of each observation's fitting results and a high degree of user control over its output products and processing methods. We test ASAD_uv against mock UV integrated spectra based on the MILES library, created by adding random Gaussian noise (for SNRs of ~1-10) which is typical for real UV observations.

KEYWORDS UV, clusters, spectra, fitting, stellar, age, modeling

FM 4

#1669

Metallicity-dependent mixing length in the evolutionary model from red supergiant stars in IC 1613

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We investigate near-infrared low-resolution spectroscopy for red supergiant stars (RSGs) in the irregular dwarf galaxy IC 1613 using the MMIRS at the MMT telescope. The effective temperatures (Teff) and metallicities of 14 RSGs are obtained by synthetic spectral fitting to the observed spectra ranging from 1.16 to 1.23 . We find a weak bimodal distribution of the RSG metallicity centered on the [Fe/H]=-0.65, which is slightly lower than or comparable to that of the Small Magellanic Cloud (SMC). We also find that the mean effective temperature of our RSG is higher by about 250 K than that of the SMC. The stellar evolutionary tracks are computed with the MESA code, and the convective mixing length (αMLT) is calibrated by comparing the evolutionary tracks with our RSG positions on the HR diagram. We find that the effective temperature of the RSGs in IC 1613 is best reproduced by the models with αMLT=2.2-2.4 HP for both Schwarzschild and Ledoux convection criteria. Using literal temperature data, we also calibrate the mixing length value for the RSGs in Wolf-Lundmark-Mellote (WLM) galaxy which is known to have the lower metallicity than IC 1613, finding that the evolution models with the mixing length of αMLT=2.1 HP reproduce well the location of WLM RSGs in HR diagram. The mixing length values for both galaxies are definitely lower than that of the Milky Way, and this result supports our previous study that the mixing length increases with increasing metallicity to explain the RSG temperature. However, we also find that this trend becomes relatively weak for RSGs having a metallicity equal to or less than the SMC metallicity.

KEYWORDS star, red supergiant, stellar evolution, galaxy, IC 1613

FM 4
#1026

Nebular C IV Imaging of Mrk 71 with HST

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Weak mechanical feedback from young, metal-poor super star clusters enhances radiative cooling of potential outflows. These conditions are predicted to elevate C IV 1550 nebular emission. We present the first nebular C IV imaging of a nearby star-forming complex. The observations are obtained with the Hubble Space Telescope using ACS/SBC, targeting Mrk 71, a starburst complex in the local, metal-poor galaxy NGC 2366. This system is a spatially resolved analog of the Green Pea galaxies and a candidate Lyman continuum emitter.

KEYWORDS ultraviolet: ISM, galaxies: starburst, star clusters, HII regions, ISM: kinematics, stars: massive, galaxies: dwarf

FM 4

#830

Spatially variable Lyα line profiles and environments in a strong LyC leaking galaxy

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The process of the reionization of the universe remains poorly understood. In the local universe, insufficient ionizing radiation escapes source galaxies to explain the amount of ionized gas observed. It is not clear what escape mechanism permitted reionization by the earliest stars and galaxies, and why this is no longer common. In light of this, we present rest-frame ultraviolet spectra of the Sunburst Arc, a z~2.4 strongly lensed galaxy which shows strong LyC leakage. We use the resonant Lyα emission line as a probe of the distribution of neutral hydrogen due to its complex radiative transfer, which encodes significant physical information about its scattering environment. Many of the lines of sight feature a triple-peaked Lyα spectral feature, which we attribute to an expanding shell of neutral hydrogen with optically thin channels which allow some direct escape. The strong lensing effect allows us to isolate the Lyα emission from physically distinct regions of the galaxy, across which we see significant spatial variations. Likewise, we also measure other spatially resolved, physically relevant quantities such as the UV slope, star formation rate, and parameters of various ISM absorption lines to further characterize the conditions of the LyC-leaking environment. Spatial variations in the Lyα profiles indicate large changes in the properties of the neutral hydrogen along different lines of sight into the galaxy. The extreme ionizing radiation and leaking LyC photons the Sunburst Arc emits are both properties associated with the galaxies responsible for re-ionizing the universe. So, though the epoch of reionization predates the age of the Sunburst Arc, this is suggestive that highly anisotropic neutral hydrogen column densities in the first generation of galaxies is likely an important factor in explaining how the universe reionized.

KEYWORDS reionization, gravitational lensing, Lyman continuum, Lyman-α, ISM absorption, star formation

FM 4
#731

UV Diagnostics of Radiatively Cooling Superwinds in Super Star Clusters

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Mechanical feedback from young, massive stars in super star clusters (SSCs) can drive galactic-scale winds, so-called superwinds, as well as hot superbubbles. Observations of SSCs in several star-forming galaxies such as M82, NGC 2366, and NGC 5253 imply that the superwinds are suppressed and/or cooled. In this study, we conducted a set of hydrodynamic simulations using the non-equilibrium radiative cooling chemistry package MAIHEM developed within the FLASH for various superwind parameters, namely mass-loss rate, terminal velocity, metallicity, and ambient density, in order to map the presence of radiatively cooling superwinds. The physical conditions generated by our hydrodynamic simulations were employed for photoionization calculations with CLOUDY to create UV diagnostic diagrams with emission lines such as He II 1640, C IV 1550, and O VI 1032. Our UV diagnostic diagrams might help us recognize better superwinds with radiative cooling in star-forming regions.

KEYWORDS Superwinds, Super Star Clusters, UV diagnostics, Radiative Cooling, Superbubbles, Young Massive Stars, Star-forming Regions

FM 4
#443

A New Probe of Dust Attenuation in Star-Forming Galaxies

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We present a novel method to measure the interstellar reddening in star-forming galaxies. The ability to robustly determine galaxy properties such as masses, ages and star-formation rates is critically limited by the ability to accurately measure dust attenuation. Dust reddening is often characterized by comparing observations to models of either nebular recombination-lines or the UV continuum. Here, we use a new technique to measure dust reddening by exploiting emission line features caused by the stellar winds of Wolf-Rayet stars. The He II 1640 and 4686 features are recombination lines caused by these winds, which have an intrinsic ratio primarily determined by atomic physics. As a result, the two spectral lines can be used to look at stellar reddening similarly to how the Balmer lines probe reddening of gas emission. These lines have been observed in galaxies within the local universe out to a redshift of 3, and will be detected at higher redshifts with JWST. Using this third dust probe as a complement to both the Balmer decrement and the stellar absorption provides a significant improvement to our understanding of dust attenuation by allowing us to study the stellar and nebular components separately. It also allows us to test the effects of dust at different stellar age and mass regimes. We present new optical and UV spectra from star-forming regions in eight nearby star-forming galaxies obtained for this project with HST STIS and discuss first results.

KEYWORDS dust, starburst galaxies, Wolf-Rayet-Stars, star clusters, stellar evolution, massive stars

Studying the age of supergiant companions in the magnetized X-ray binaries

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It has been proposed multiple times to use the neutron star (NS) in high-mass X-ray binaries (HMXBs) as an orbiting X-ray probe embedded in the wind-fed of its supergiant (SG) companion in order to constrain the stellar line-driven wind from the SG. We demonstrate how to combine various observables of HMXBs from the X-ray accretion luminosity produced by the wind-fed NS, in order to estimate and constrain the age of the donors. This would help us to study the stellar evolution track for each donor model. Since the evolution of massive stars is essentially determined by mass loss, and that direct measures of mass-loss rates suffer from important uncertainties due to the unknown micro-structure of the wind.

KEYWORDS Binaries, supergiant, wind-fed model, formation and evolution, , magnetic fields

e-Talks

FM 4

#3033

Revisiting The Cluster Initial Mass Function of a sample of super star clusters in the disk of M82

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We revisit the Cluster Initial Mass Function (CIMF) of the sample of super star clusters in the disk of the prototypical starburst galaxy M82, characterized in Cuevas-Otahola et al. (2021). This CIMF was widely discussed in the work by de Grijs (2003), using a rough analytical approximation, addressing whether the CIMF follows a power-law (Fall & Zhang 2001) or a log-normal function (Vesperini 1998, 2000, 2001). In order to throw light on this subject, we use the semi-analytical code of dynamical evolution Evolve Me a Cluster of Stars (EMACS, Alexander et al. 2014), to simulate the CIMF and its evolution over initial log-normal and power-law mass functions, to give insights into which function better describes the CIMF, finding the best agreement with the latter one for a slope $\alpha = 1.8$, shallower than the typical CIMF of $\alpha = 2.0$. Since the population of M82 disk clusters is nearly coeval, with a peak age close to 100 Myr, M82 offers a great opportunity to understand the origins of the CIMF. We consider the work by Mayya et al. (2008) and Cuevas-Otahola et al. (2021), to reproduce the observational biases in the simulated mass distribution in order to perform a proper comparison of our results with the observed sample. We compare our results in the mass-radius diagram, finding good agreement with the observed mass-radius relation.

KEYWORDS M82, Super Star Clusters, Young Clusters, CIMF, Extragalactic Clusters, Clusters Dynamics, HST

FM 5

Beyond the Goldilocks Zone: the Effect of Stellar Magnetic Activity on Exoplanet Habitability

Invited & Contributed Talks

FM 5

#297

Recent Developments in the Babcock-Leighton Dynamo Theory for the Solar Cycle

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The magnetic field of the Sun increases and decreases in time with a polarity reversal every 11 years. The most interesting aspect here is that the amplitude of the field does not grow all the time, although there is a considerable variation in time. It is believed that a dynamo mechanism, operating in the convection zone of the sun, is responsible for producing these peculiar features in the magnetic field. Based on the limited observations of the solar magnetic field in the 1960s, Babcock and Leighton proposed a mechanism for the maintenance of the solar cycle. However, due to insufficient observational facts, scientists barely recognised this idea, rather tried to model the magnetic cycle through MHD convection simulation which eventually gave a little success. In recent years, long-term data produced from different observatories enabled us to validate the original idea of Babcock and Leighton. After giving some historical developments of this idea in this presentation, I shall discuss how well the solar cycle can be explained through the dynamo models developed based on the Babcock-Leighton mechanism. I shall also highlight different nonlinear mechanisms responsible for regulating the solar cycle amplitude, causes for making the cycle irregular, and the scope for prediction.

KEYWORDS Solar cycle, Solar Magnetic field, sunspot, Magnetohydrodynamics

FM 5

#2902

Modelling the occurrence of grand minima in sun-like stars using a dynamo model

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There is some observational evidence that rapidly rotating and young Sun-like stars exhibit a high level of activity with no Maunder-like grand minimum (flat activity) and rarely display smooth regular activity cycles. On the other hand, slowly rotating old stars like the Sun and older have lower activity levels and smooth cycles with occasional grand minima. We want to explain this observational trend using a simple Babcock–Leighton dynamo model. Following previous work (Karak, Kitchatinov & Choudhuri 2014), we build kinematic dynamo models of one solar mass star with different rotation rates and depth of convection zones. We specify the large-scale flows (differential rotations and meridional circulations) from corresponding hydrodynamic models. We include stochastic fluctuations in the Babcock-Leighton source for the poloidal field to produce variable stellar cycles. We observe that the rapidly rotating stars produce highly irregular cycles with strong magnetic fields and rarely produce Maunder-like grand minima, whereas the slowly rotating stars (Sun and longer rotation period) produce smooth cycles of weaker strength and occasional grand minima. In general, the frequency of occurrence of the grand minima increases with the decrease of rotation rate. These results can be explained by the fact that with the increase in rotation period, the supercriticality of the dynamo decreases, and the dynamo is more prone to produce extended grand minima in this regime.

KEYWORDS Solar dynamo, Stellar dynamo, Stellar magnetic field, Stellar magnetic activity, Grand minima

FM 5

#1713

Effect of planetary magnetic fields in the planetary habitability

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As planets age and lose their interior heat through convection, the liquid metals flowing in their interior act as an efficient dynamo, giving rise to the planetary magnetic fields. Most planets in our solar system, and some moons, either have a magnetic field or had it in the past. Depending on the physical properties of a planet, its magnetic field can take a wide variety of strengths and morphologies. The magnetic fields most likely affect the habitability of a planet through altering the way the stellar winds interact with the planetary atmosphere. One can imagine that magnetic fields provide a protective cocoon around a planet, which may shield the atmosphere from stellar wind driven erosion. However, extensive computational, theoretical, and observational work done in recent years have painted a much more intricate picture of the role played by the planetary magnetic fields. In this review talk, I will summarise the recent work done in this context and discuss what kind of magnetic field properties are suitable for promoting the habitability of a planet.

KEYWORDS Magnetic fields, Habitability, planets

FM 5

#1893

Stellar magnetic fields and the solar-stellar connection

Stephen Marsden[1]

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The Sun has long been of central importance in our understanding of the magnetic fields of many other stars. This is because the long time-base of solar observations and our close-up view means that our picture of solar magnetic fields remains significantly more detailed than that of other stars. Nevertheless, over the last few decades, techniques such as Zeeman Doppler Imaging (ZDI) have delivered major advances in the observational study of stellar magnetic fields as we can now map global stellar surface magnetic topologies to survey stars of different masses, ages, and rotation rates. Using these surface field maps we can also observe changes in stellar magnetic fields akin to the Sun's 22-year magnetic cycle and use these maps at a given epoch to model stellar winds. These advances in turn enable increasingly detailed comparisons as to the origins and evolution of solar and stellar magnetic fields. In this talk I will give an overview of how stellar activity and magnetic field studies are used to make mutually beneficial solar-stellar connections.

KEYWORDS stellar magnetism, stellar activity, solar-stellar connection

FM 5
#601

Near-infrared Zeeman-Doppler Imaging of AD Leo with SPIRou: towards a magnetic polarity reversal?

Stefano Bellotti[1], **Julien Morin**[2], **Lisa Lehmann**[3], **Colin Folsom**[4], **Alexis Lavail**[5], **Pascal Petit**[3], **Gaitee Hussain**[6]

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Zeeman-Doppler Imaging has been applied on numerous stars to reconstruct their surface magnetic field topology and provide observational feedback on their internal structure. Several types of magnetic field topologies in low-mass fully convective stars have been reported and their explanation requires either two coexisting and stable dynamo branches (known as dynamo bistability) or long-term magnetic cycles with polarity reversals, but there is no definite conclusion on the matter. Magnetic cycles are also known to introduce spurious radial velocity signatures preventing a reliable detection and characterisation of exoplanets, and modulate the stellar radiation output in which close-in planets are embedded. This leads to a temporal variation in the planetary atmospheric stripping, and alteration of the chemical properties and habitability.

We analysed near-infrared spectropolarimetric observations of the active M dwarf AD Leo taken with SPIRou at CFHT between 2019 and 2020. We examined the long-term behaviour of the longitudinal magnetic field and we recovered the magnetic field geometry via both Zeeman-Doppler Imaging and a Principal Component Analysis. Including the optical data sets investigated in previous studies, we found evidence of a secular evolution of the magnetic field in the form of a varying intensity and reduced axisymmetry (from 90% to 50%), while the topology remained simple, i.e. predominantly poloidal and dipolar throughout the entire time series. This suggests that low-mass M dwarfs with a dipole dominated magnetic field can undergo magnetic cycles.

KEYWORDS Stellar magnetic fields, Activity, Cycles, Planet characterisation, Habitability, Spectropolarimetry

FM 5

#422

What makes a stellar surface preferentially facular or spot dominated?

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The photospheres of sunlike stars have been found to display a smooth transition between being dominated by spots or by faculae features. We found that the Sun lies in the transition between the spot and faculae domination regime. Some hypotheses have been explored suggesting that such surface manifestations may correlate with different magnetic dynamo modes. By using a recently developed method based on the Gradient of the Power Spectra (GPS), we quantified the ratio between faculae to spots signature based on solar and stellar light curves. We characterized a sample of 30 sunlike stars, with and without detected exoplanets, which we have identified to have different levels of spot- or faculae-dominance on their surface. We analyzed the longitudinal magnetic field, additional activity indicators such as the S-Index from the calcium H&K core line, H-alpha, and the Ca triplet in the near-infrared. We interpret the differences between having spot versus faculae dominated stellar surfaces in the context of possible different effects over their stellar environment and planetary habitability.

KEYWORDS Faculae, Spots, Magnetism, Habitability, Sun-like stars

FM 5
#2432

Solar Flares - an observational overview

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The highly dynamic solar magnetic field drives the activity of the Sun. In certain configurations, the magnetic field can reconnect and cause very powerful eruptions: solar flares.

Flares affect space weather, which manifests itself on Earth as enhanced auroral activity, and potentially, satellite damage and power outages. Yet several important questions remain open: When will the next flare occur? Can the Sun produce as as strong flares as observed on some sun-like stars? What happens during flares in the solar atmosphere and how is their energy converted?

In this review, I will provide a summary of solar flares and present recent results from ground- and space-based flare observations.

KEYWORDS flares, sun

FM 5
#782

On the Formation of Solar Superstorms

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An extreme space weather storm is termed a low-probability, high-consequence event, otherwise called a solar superstorm. We discuss the formation of solar superstorms based on a comparative study of the 2012 July 23 and 2017 July 23 eruptions. The first one is Carrington-class, and the second could rival the 1989 March event that caused the most intense geomagnetic storm of the space age. Observations of these events in the historically weak solar cycle 24 indicate that a solar superstorm can occur in any solar cycle and at any phase of the cycle. Recurrent patterns are identified in both cases, including the long-lived eruptive nature of the active region, a complex event composed of successive eruptions from the same active region, and in-transit interaction between the successive eruptions resulting in exceptionally strong ejecta magnetic fields at 1 AU. Preconditioning of the upstream solar wind leading to unusually high solar wind speeds at 1 AU is observed in the first case whereas not in the latter. This may suggest that the concept of "preconditioning" appears to be necessary for making a Carrington-class storm. Both cases can be classified as an "ICME-in-sheath" (IIS) phenomenon, a completely shocked interplanetary coronal mass ejection (ICME) stuck in the sheath between a shock and host ejecta. An IIS is anticipated to occur frequently. Through coordinated multi-sets of observations, additional examples are identified and their typical characteristics are found. On the basis of these results, we propose a hypothesis that superstorms are "perfect storms" in nature, i.e., a combination of circumstances that results in an event of unusual magnitude. Historical records of some extreme events seem to support our hypothesis.

KEYWORDS extreme space weather, solar superstorms, perfect storms, coronal mass ejections, shocks

FM 5

#1539

Coronal mass ejections associated with DH type II radio bursts: near-Sun characteristics and interplanetary propagation

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We explore the near-Sun and interplanetary characteristics of Coronal Mass Ejections (CMEs) associated with DH type II bursts for the Solar Cycles 23 and 24. The novelty of the study lies in classifying the DH type II bursts into three categories: Low-Frequency Group (LFG; 20 kHz ≤ f ≤ 200 kHz), Medium-Frequency Group (MFG; 200 kHz < f ≤ 1 MHz), and High-Frequency Group (HFG; 1 MHz < f ≤ 16 MHz). We find that the sources for LFG, MFG, and HFG events are homogeneously distributed over the active region belt. Our analysis shows a drastic reduction of the DH type II events during Solar Cycle 24, which includes only 35% of the total events (i.e., 179 out of 514). Despite having smaller number of DH type II events in the Solar Cycle 24, it contains a significantly higher fraction of LFG events compared to the previous cycle (32% versus 24%). However, within the LFG group, the cycle 23 exhibits significant dominance of type II bursts that extend below 50 kHz, suggesting rich population of powerful CMEs traveling beyond half of the Sun-Earth distance. The events of LFG group display strongest association with faster and wider (more than 82% events are halo) CMEs, whereas at the source location, they predominantly trigger large M/X class flares (in more than 83% cases). Our analysis also indicates that CME initial speed or flare energetics is partly related to the duration of type II burst and that survival of CME-associated shock is determined by multiple factors/parameters related to CMEs, flares, and state of coronal and interplanetary medium. The profiles relating CME heights with respect to the end frequencies of DH type II bursts suggest that for HFG and MFG categories, the location for majority of CMEs (≈65%–70%) is in well compliance with ten-fold Leblanc coronal density model, whereas for LFG events, a lower value of density multiplier (≈3) seems to be compatible.

KEYWORDS Coronal mass ejections, Interplanetary, Magnetic fields, Type II radio bursts, Meter-wavelengths and longer, Active regions

FM 5

#939

Coronal Mass Ejections and Exoplanets: A Numerical Perspective

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Flares and coronal mass ejections (CMEs) are more energetic than any other class of solar phenomena. They involve the rapid release of up to 1033 erg of magnetic energy in the form of particle acceleration, heating, radiation, and bulk plasma motion. Displaying much larger energies, their stellar counterparts are expected to play a fundamental role in shaping the environmental conditions around low-mass stars, in some cases with catastrophic consequences for planetary systems due to processes such as of atmospheric evaporation and erosion. While flares are now routinely detected in multi-wavelength observations across all spectral types and ages, direct evidence for stellar CMEs is almost non-existent. In this context, numerical simulations provide a valuable pathway to shed some light on the eruptive behavior in the stellar regime. I will review recent results obtained from realistic modeling of CMEs in active stars, highlighting their key role in the interpretation of currently available observational constraints. Emphasis will be given to M dwarfs, focusing on how the emerging EUV/X-ray/Radio signatures from these events vary as a function of the magnetic properties of the star. I will also present our latest simulations of extreme CMEs from the flare star AU Mic, and how these energetic events are expected to affect the two recently discovered exoplanets of this system. Finally, I will discuss the implications and relevance of these numerical results in the context of future characterization of host star-exoplanet systems.

KEYWORDS Stellar Activity, Stellar Coronal Mass Ejections (CMEs), Stellar Magnetism, Exo-Space Weather, Magneto-Hydrodynamics

FM 5
#1451

Recent studies of stellar flares across the electromagnetic spectrum

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In recent years, the detection of potentially habitable planets around sun-like stars and red dwarf stars reached a new peak due to missions like Kepler/K2 and TESS. However, the true habitability of these and other candidates depends strongly on the activity of their parent stars. And flares, together with CMEs, are the most explosive manifestations of stellar activity.

Despite the fact that stellar flares can be several orders of magnitude more energetic than their solar counterparts, they are considered to be similar in origin and development. In general, they are believed to arise from the rupture of a stressed magnetic structure, which by magnetic buoyancy is forced upwards through the photosphere into the corona and transition region. The topology of the magnetic field changes rapidly through magnetic reconnection and is followed by a considerable release of energy. This, in turn, leads to bright and (relatively) short radiation throughout the electromagnetic spectrum - from X-rays to radio wavelengths. Here I will attempt a review of the most interesting recent results in the study of stellar flares in all these domains, based on both new instruments and techniques, as well as the most recent models and simulations.

KEYWORDS stars: activity, stars:flares, stars:multiwavelength observations, stars:spectroscopy, stars:photometry

FM 5

#2473

Radio Dynamic Spectroscopy of UV Cet and Prox Cen

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Motivated by the possibility that radio analogs to solar radio bursts of type II, III, and IV - signatures of solar activity and space weather drivers - may be detectable on late-type dwarf stars the South African radio telescope MeerKAT was used to perform high bandwidth, high sensitivity dynamic spectroscopy at decimeter wavelengths of the archetypical flare star UV Cet (M6V) and the nearest star and planetary system Prox Cen (M5.5V). Although similar in spectral type the manifestations of magnetic activity at radio wavelengths differ dramatically on the two stars. A large radio outburst with a duration of 2 hr was observed on UV Cet. The spectra show surprising richness with fine structures drifting in time and frequency. The emission is strongly right circularly polarized, in general, although several elliptically polarized burst components appear late in the event. We present a simple model that appears to be broadly consistent with the characteristics of the radio emission from UV Cet, showing that the emission is auroral in nature. In contrast, Prox Cen produced several radio flares that were either right- or left-circularly polarized, closer in nature to those conventionally attributed to flare-like activity on late-type stars. Neither star produced radio bursts analogous to solar radio bursts. Implications for planets in the habitable zone are briefly discussed.

KEYWORDS UV Cet stars, Flare stars, magnetic fields, Radio emission, Exoplanets

FM 5
#950

The effects of stellar flares on the composition and spectra of gaseous exoplanets orbiting M dwarfs

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Stellar flares of active M dwarfs can affect the atmospheric composition of close-orbiting gaseous giant planets. This can introduce a time dependence to measured transmission spectra, which in turn can bias retrieval analyses. Existing studies that have researched this effect have not accounted for climate dynamics and its possible relevance to the atmosphere's response and have not explored the large diversity of flare events.

We have investigated the effects of stellar flares on the chemical composition of a tidally-locked, close-orbiting gaseous planet with an effective temperature of 800 K and considered the impact on the transmission spectra. We use a two-dimensional thermo-and photochemical kinetics model that takes into account horizontal transport due to equatorial superrotation, the latter dominating the circulation patterns of such planets. We explore a variety of flares that differ in energy, duration, and occurrence frequency.

We find that a high-energy flare event depletes the dayside and evening limb in methane and ammonia by over 3 orders of magnitude, which lowers transit depths by 200 ppm during the first several days after the flare event on the evening limb spectrum. When advected to the cooler nightside, photodissociation products recombine and enhance the molar fractions of hydrogen cyanide and acetylene. The latter molecule causes a strong increase in transit depth (< 600 ppm) on the morning limbs spectrum around 14 microns for several days after the flare, although this is strongly coupled to the horizontal wind speed. We identify the peak flux of the flare event as the most important factor in determining the chemical response of the atmosphere. Finally, we find that rare high-energy flares do not have a lasting effect on the chemical composition.

KEYWORDS stellar flares, giant planets, planet atmospheres, atmospheric composition

FM 5
#1907

Characteristic time of stellar flares on Proxima Centauri

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Proxima Centauri is the nearest star to our solar system. It is flare productive and the flares can impact habitability of exoplanets in Proxima system. Although Proxima has no spatially resolved observations comparable to the Sun, the time scale of flares can provide useful information about spatial scale of flare source regions on Proxima. By using the 20-second cadence light curve data of Proxima collected by the TESS mission, we show that the most probable value of flare rise time of Proxima is 0.53±0.17 minutes which is 6.6±2.2 times shorter than Sun-like stars, and the most probable value of flare decay time of Proxima is 7.0±1.9 minutes which is 2.1±0.6 times shorter than Sun-like stars. This result indicates that the spatial scale of flare source regions on Proxima is several times smaller than that on Sun-like stars and the Sun.

KEYWORDS Stellar flare, Characteristic time, Proxima Centauri

FM 5
#1598

Pre-main Sequence Stellar Megaflares and Young Planetary Atmospheres

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X-ray and Extreme Ultra-violet (XUV) emission of young stars can have major effects on young planets including photoevaporation of H-rich atmospheres and evolution of their magma ocean environments. Most are based on overly simplistic XUV radiation fluxes without full consideration of stellar X-ray properties. Here we describe a research program using NASA's Chandra X-ray Observatory that provides quantitative measures of XUV evolution as a function of stellar mass and age from 0.5 Myr to 25 Myr. Thousands of young stars with known masses and ages are analyzed with sophisticated statistical methods. ``Continuous'' X-ray luminosities and individual flare events are considered independently as they have different temporal behaviors and penetration into planetary atmospheres.

During the early pre-main sequence (PMS) phase (0.5-5 Myr), the XUV driven photoionization can efficiently evaporate the inner parts of a protoplanetary disk. Disks and primordial atmospheres of "infant" exoplanets around solar-mass stars are blasted by millions of X-ray mega-flares with log E_x > 36 erg, each thousands of times more powerful than super-flares seen in older (300-600 Myr) stars by the Kepler mission. During the late PMS phase (5-25 Myr) when solar mass stars move across the Hertzsprung-Russell diagram towards the ZAMS, X-ray luminosities fall slowly for masses < 1 M_o and rapidly for masses >1 M_o as the convective alpha^2 dynamo is replaced by a solar-type alpha-Omega dynamo. X-ray emission plummets for fully radiative stars. We hope to measure late-PMS flare rates and extend this analysis to ZAMS stars with ages 25-100~Myr.

The ``continuous'' X-ray luminosities of late-PMS stars can be so high that a young inner Earth-mass rocky, unmagnetized planet might lose its primary and secondary atmospheres within several million years. If the response of the planetary atmosphere escape to additional ionization is rapid (<1 day), then mega-flare irradiation with associated coronal mass ejection driven shocks and energetic particles can provide substantial impact on the chemistry and dynamics of atmospheres of young exoplanets.

KEYWORDS flares, pre-main sequence stars, planetary atmospheres, X-rays

FM 5

#1854

Hunting for stellar coronal mass ejections

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Solar/stellar flares are energetic explosions on the surface. Solar flares are often accompanied by filament/prominence eruptions, sometimes leading to coronal mass ejections (CMEs) that directly affect the Earth's environment. By analogy, we expect that stellar flares are also associated with stellar CMEs. Characterizing stellar CMEs is essential to knowing the impact on exoplanet habitability. Probable detections of stellar CMEs are still rare, but in this decade, many attempts have been made to find them in many ways, such as spectroscopic observations of stellar flares. Some research has reported that flares on M/K-dwarfs and giant stars sometimes show blue-shifted Balmer/X-ray emissions lines (e.g., Vida et al., 2016, Argiroffi et al., 2019). These are interpreted as stellar prominence eruptions/CMEs. More recently, a blue-shifted absorption of Hα line is found to be associated with a large "superflare" on a young Sun-like star, which is evidence of a stellar filament eruption, probably leading to a CME (Namekata et al., 2022). The time evolution of Hα profiles dramatically resembles those of solar filament eruptions, indicating that the solar/stellar events share the same picture, although their energy scales are different. These research reported that the erupted mass increases as the flare energy increases. Notably, the erupted masses for "superflares" are larger than those of the largest solar CMEs, indicating a severe influence on exoplanet environments. The erupted masses are consistent with those expected from the solar scaling relation, which may indicate a common relation between flares and CMEs on the Sun and stars. On the other hand, the ratio of the kinetic energy of stellar CMEs to flare energy is significantly smaller than expected from the solar scaling relation. This discrepancy may be due to the magnetic suppression by the large-scale magnetic field but may be due to the velocity difference between filament eruptions and CMEs. In addition to these methods, post-flare XUV dimming is reported for M/K-dwarfs as an indicator of CMEs (Veronig et al., 2021), and characterization of CME properties using this method is also expected in the future. In this review, we will summarize these recent observations of coronal mass ejections from cool stars and discuss influences on exoplanetary systems.

KEYWORDS solar/stellar CMEs, solar/stellar flares, filament/prominence eruption, exoplanet habitability

FM 5

#1575

Where are the stellar coronal mass ejections?

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Flares and coronal mass ejections (CMEs) can have serious effects on their surroundings: they can erode or completely destroy atmospheres of orbiting planets over time and also have high importance in stellar evolution. Most of the CME detections in the literature are single events found serendipitously sparse for statistical investigation.

I present a search in archive spectra of dwarf stars from solar-like objects to M-dwarfs aimed to find a large number of stellar CMEs suitable for statistical analysis. For M-dwarfs, we found event rates that are lower than we could expect from the solar paradigm, and no convincing events for solar-like stars. What can be behind this low number of events? Can high-resolution solar spectra help us to learn more on stellar CMEs?

KEYWORDS coronal mass ejections

FM 5

#2346

Trying to catch the elusive stellar coronal mass ejections

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Coronal mass ejections (CMEs) are explosive events that occur basically daily on the Sun. It is thought that these events play a crucial role in the angular momentum loss of late-type stars, and also shape the environment in which planets form and live. Even though they are crucial phenomena, basically nothing is known about the stellar CMEs. They are extremely challenging to detect. So far, only a handful of events that have been interpreted as stellar coronal mass ejections have been observed. In this talk we will present our time-series Halpha observations of several cool stars, both solar-like and M dwarfs. Even after many hours of observations, only very few events indicating possible stellar CMEs have been observed. Here, we will discuss our detection rates and observational challenges in detecting stellar CMEs.

KEYWORDS

FM 5
#2347

Space weather response to large-scale solar wind drivers

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Coronal mass ejections (CMEs), stream interaction regions (SIRs) and fast streams are they primary drivers of space weather at the Earth and other planets of our solar system. In interplanetary space CMEs are typically composed of a leading shock, turbulent sheath and a driving ejecta that can feature signatures of a magnetic flux rope. SIRs in turn form when the fast wind crashes the slow wind ahead, while the key characteristics of fast streams that originate from coronal holes are embedded Alfvenic fluctuations. CMEs, SIRs and fast streams (and their substructes) have thus inherently different origin and solar wind conditions, and as a consequency, they cause distinct responses to planetary magnetospheres and ionospheres, including the radiation belt regions and precipitation of energetic electrons from them to the upper atmosphere. This presentation gives an overview of these different space weather drivers and typical responses they cause. The conditions for extreme space weather at differnt regimes will be alos discussed.

KEYWORDS space weather, coronal mass ejection, shocks

FM 5

#1190

Stellar space weather effects on potentially habitable planets

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Stellar activity can reveal itself in the form of radiation (eg, enhanced X-ray coronal emission, flares) and particles (eg, winds, coronal mass ejections). Together, these phenomena shape the space weather around (exo)planets. As stars evolve, so do their different forms of activity -- in general, younger solar-like stars have stronger winds, enhanced flare occurrence and likely more frequent coronal mass ejections. Altogether, these effects can create harsher particle and radiation environments for habitable-zone planets, in comparison to Earth, in particular at young ages. In this talk, I will review some effects of these harsher environments on potentially habitable exoplanets.

KEYWORDS stellar activity, exoplanets, space weather

Towards a better understanding of exoplanetary environments around cool stars

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Surveys focused on low-mass stars have found a relatively large number of exoplanets near their host star, some of which orbit within the extended coronal structures (0.1-0.4 au). In this proximity, the planets are exposed to high-energy radiation and extreme space-weather conditions, leading to new hazards such as increased susceptibility to stellar activity and rapid atmospheric escape. A detailed parameterization of the magnetized winds is critical, especially for the low-luminosity active M dwarfs with nearby "Habitable zones" (HZs), defined as the range of orbits where an Earth-like planet could harbor surface water. These stars host rocky planets that are most likely the only potentially habitable planets whose atmospheres could be successfully probed for signs of life. We are using one of the best 3D physics-based solar models to date and applying it to the stellar wind domain. In this talk, I will show how the features of the stellar wind that shape planetary atmospheres are affected by the properties of the star. I will also discuss the relevance of these results by considering a possible restriction on the classical HZ that accounts for the expected local stellar wind conditions as a function of the magnetic field properties of the host star.

KEYWORDS cool stars, Habitable Zone, Space weather, Stellar winds, Magnetic field, planetary atmosphere, Mdwarfs

FM 5

#1154

Planet-enhanced activity from M dwarfs

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Close-in exoplanets can interact with the magnetic field of their host star, producing Alfvén waves which travel back towards the star. The mechanical energy carried by these waves is thought to dissipate in the corona of the star, powering electromagnetic radiation at different wavelengths. One possible signature of these interactions is the enhanced emission of chromospheric lines such as Ca II H & K and He I, which are well-established tracers of stellar activity. In order to assess the likelihood of these interactions occurring, we need to know the plasma conditions of the interplanetary environment, which are not generally measurable with current observing techniques. They can however be obtained by coupling sophisticated magnetohydrodynamic models with both observationally-derived stellar surface magnetic field maps and mass-loss rate estimates. In this presentation, I will discuss how these models can allow us to both interpret and predict planet-enhanced activity in observations of chromospheric lines from M dwarfs. Such observations and their interpretation in the optical domain are also greatly complemented by radio observations, which are also thought to trace star-planet interactions via the electron cyclotron maser instability.

KEYWORDS stellar activity, star-planet interactions, close-in exoplanets

Astronomy for All
Busan 2022

FM 5

#430

Evolution and diversity of the magnetism of the Sun and Sun-like stars

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The solar magnetic field is generated and sustained through an internal dynamo. This process is determined by the combined action of turbulent convective motions and differential rotation. It can sometimes lead to magnetic cyclic variabilities, like in the Sun with the 11 years cycle. Evidence of magnetic cycles have been detected for other solar-type stars as well, ranging from a few years to a few tens of years. How are these cycles controlled?

During their life, the rotation of stars is subject to a complex evolution. Recent 3D numerical simulations of solar-type stars show that different regimes of differential rotation can be characterized with the Rossby number. In particular, anti-solar differential rotation (fast poles, slow equator) may exist for high Rossby number (slow rotators). If this regime occurs during the main sequence, and in general for slow rotators, we may wonder how the dynamo process will be impacted, and if our Sun is approaching such a transition, e.g. can slowly rotating solar-type stars maintain a regular cycle activity?

I will present a numerical multi-D dynamo study with the STELEM and ASH codes to understand the magnetic field generation of solar-type stars under various differential rotation regimes, and focus on the existence of magnetic cycles in a "Sun in Time" context.

We find that short cycles are favoured for small Rossby numbers (fast rotators), and long cycles for intermediate (solar-like) Rossby numbers. Slow rotators (high Rossby number) are found to produce only statistically steady dynamo with no cyclic activity in most cases considered.

We further assess the various energy transfers in these stellar dynamos and quantify the amount of magnetic energy available (up to 3% of the stellar luminosity) to power possible surface eruptive events.

https://ui.adsabs.harvard.edu/abs/2022A%26A...658A.144N/abstract
https://ui.adsabs.harvard.edu/abs/2022ApJ...926...21B/abstract

KEYWORDS solar dynamo, solar magnetic fields, stellar magnetic fields, solar differential rotation, stellar rotation, stellar activity, magnetic cycles

e-Posters

FM 5

#2274

What is the influence of sun-like magnetic cycle on exoplanetary atmospheric escape?

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Radiation from host stars (e.g., X-ray and UV) is one of the main sources of driving exoplanetary wind and affecting exoplanetary atmospheric escape. Given that the stellar irradiation depends on the stellar magnetic field and stars have the magnetic cycle, we investigate the cyclic evolution of exoplanetary atmospheric escape. We use the solar EUV data which is strongly correlated with the solar magnetic cycle as a guide to get the time variation of EUV fluxes from sun-like stars and simulate the evolution of atmospheric escape using a 1D hydrodynamic escape model. This 1D hydrodynamic escape model is widely used to study the physical properties of exoplanetary atmospheres and their mass-loss rate. We find that the mass-loss rate from the planetary atmosphere shows a cyclic variation with the magnetic cycle of host stars, which can affect the observational signatures in Lyman-alpha and H-alpha lines. Whether the variation of mass loss rate is significant during a cycle solely depends on how strong or weak that cycle would be. Finally, we use available magnetic maps of the star HD189733 from the Zeeman Doppler Imaging (ZDI) technique to get EUV fluxes and study the atmospheric escape from the exoplanetary system to compare the results with available spectroscopic transit observations.

KEYWORDS stellar cycle, atmosheric escape, habitability

FM 5
#2436

On the Habitability of Teegarden's Star planets

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We study the habitability of the two ~1 Earth-mass planets, detected in 2019 by the CARMENES collaboration, around the nearby M8-dwarf Teegarden's Star. Both planets are within the Habitable Zone and likely to be tidally locked. Applying an analytic habitability model for locked (Wandel 2018) and synchronously rotating (Wandel and Gale 2020) planets, we find that surface liquid water could be present on both planets for a wide range of atmospheric properties, which makes them attractive targets for biosignature searches. The prospects of the planets retaining such an atmosphere over their history, in spite of the early violent evolution of their host are discussed.

KEYWORDS stars: individual (Teegarden's Star), planets and satellites: atmospheres

FM 5

#2111

Do Cosmic Rays surface radiation doses impact exoplanetary habitats or habitability conditions?

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Cosmic Rays (CR) incidence, as energetic particles that interact with a planetary atmosphere undergoing hadronic and electromagnetic interactions, can play an important role in habitability. To compute CR surface radiation doses is relevant to assess an eventual impact on the habitats of potential ecosystems on the planet. Atmosphere and planetary magnetic field shielding are two key factors in protecting the surface from CR radiation, that must be taken into account when computing muon, electron or gamma doses.

From our experience on Earth studies, we are now interested in estimating CR fluxes for diverse selected Earth-like exoplanets in their habitable zones, around G, K and M stars. We consider different atmospheric configurations to simulate the interactions of cosmic rays and obtain their flux at the surface. A GCM-1D climate model is used for the atmospheric profiles and CR atmospheric propagation is simulated using AIRES software. Various magnetic field options are considered for the planets, and stellar-planet properties are obtained from the literature.

Resulting vertical fluxes, average energies and surface radiation doses are discussed in comparison to equivalent Earth values, taken as reference. A summary of the study would be here presented.

KEYWORDS Cosmic Rays, surface radiation doses, Earth-like exoplanets, exoplanetary habitability

Impact of Solar-Stellar Winds on Exo(Planetary) Environments: Implications for Atmospheric Losses and Habitability

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The magnetized plasma winds of stars interact with the environment of planets that they host. This interaction is mediated via magnetic reconnection and depends on the absence or presence of a planetary magnetosphere, and the relative strengths of stellar wind and planetary magnetic fields. Based on simulations with a Star-Planet-Interaction Module we have developed – named CESSI-SPIM – we explore the dynamics and consequences of the interactions of stellar winds with planetary magnetospheres. We validate our simulations with observations of the Sun-Earth and Sun-Mars systems and demonstrate how planetary atmospheric losses may be induced by such star-planet-interactions. We discuss the implications of our results for the coupled evolution of star-planet systems and (exo)planetary habitability.

KEYWORDS Stellar wind, Magnetosphere, Planets, Star Planet Interactions, Exoplanets, Habitability, Stellar Magnetism

FM 5

#1587

Spot temperatures from line depth ratios

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Here we present a new and refined line depth ratio -- temperature calibration for data taken with the echelle spectrograph (R=21000) mounted on the 1-m RCC telescope at Piszkéstető Mountain Station, Konkoly Observatory, Hungary. Based on this calibration system, we determine precise stellar spot temperatures for several active stars of different evolutionary status using time series observations.

KEYWORDS stellar activity, stellar spectroscopy, stellar spots

FM 5

#1582

Doppler imaging with easily accessible instrumentation

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Here we present Doppler images of well-known active dwarfs and giants using time series spectra taken with the R=21000 echelle spectrograph mounted on the 1-m RCC telescope at Piszkéstető Mountain Station, Konkoly Observatory, Hungary. We present tests to show that with proper settings, the basic properties of the surface features can be constrained reliably at this spectral resolution, which helps us understand the behavior of the large scale magnetic fields.

KEYWORDS stellar activity, doppler imaging, stellar spectroscopy, stellar spots

FM 5
#1304

Saturated magnetic field and dynamics of a spatial spectrum of the Weibel instability in an anisotropic wind plasma with a kappa particle distribution

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In the physics of the coronal mass ejection, stellar flares and winds, the saturation and nonlinear evolution of a spatial spectrum of the Weibel instability, which is caused by an anisotropy of the particle velocity distribution and forms a quasi-magnetostatic turbulence during various transient processes, are important. We consider a bi-kappa distribution of particles typical for the coronal and wind plasmas and compare the results with those known for a bi-Maxwellian one. The work is based on the original (quasi-linear) codes for 1D and 2D modeling of the Weibel TM instability in a collisionless plasma. In several realistic cases, we solve a nonlinear system of the Maxwell-Vlasov equations for many hundreds of spatial harmonics via the Leapfrog numerical method.

In a wide range of both small and large values of the degree of initial anisotropy, the saturated magnetic field is found, its further slow nonlinear decay is traced, characteristics of the energy-carrying harmonics of turbulence are established, laws of variation in the width of their spectrum along and across the anisotropy axis is determined, typical patterns of deformation (flattening) of the particle velocity distribution function are pointed out, and temporal dependences of the change in effective temperatures and degree of anisotropy of these distributions are obtained.

A comparative analysis of the results obtained for 1D and 2D problems as well as for small and large (compared to unity) initial anisotropies is carried out. In particular, it is found that only for a small anisotropy degree the saturated magnetic field and the characteristic wave number of the Weibel instability with the bi-kappa distribution of particles can be much higher than those of that with the bi-Maxwellian one. Special attention is paid to the manifestation of nonlinear and/or quasi-linear effects of the interaction of various harmonics with each other and with certain fractions of the particle distribution function.

KEYWORDS stellar wind, quasi-magnetostatic turbulence, Weibel instability, bi-kappa distribution, quasi-linear dynamics, Maxwell-Vlasov equations, saturated magnetic field

FM 5

#1262

How different are the flares of giant stars from those of dwarfs?

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Using 30-minute cadence Kepler light curves we compared the flaring activity of 61 giant stars and 13 dwarfs. We found that while the morphology of the flare light curves are similar, flares on giants are more rare, but on average longer and more energetic. This could be explained by the lower surface gravity of giant stars.

KEYWORDS flares, Kepler, giant stars, dwarf stars

e-Talks

FM 5

#3325

Searching for radio stars with ASKAP - impacts on planet habitability

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I will present searches for and investigations of stellar radio emission using the Australian Square Kilometre Array Pathfinder (ASKAP). Radio emission from stars indicates the presence of strong magnetic fields, flare activity, and possible coronal mass ejections. Possible effects of such activity on orbiting planets includes atmosphere erosion and irradiation by energetic flares, reducing the habitability of such planets. To investigate the impact of radio emission on planets and the habitable zone, we first need to understand the population of radio stars and their properties. Few radio sources are strongly circularly polarised, sources with significant circular polarisation are typically pulsars or stellar sources. We use this to search for stellar radio sources in Rapid ASKAP Continuum Survey (RACS) observations. There is also a known correlation between X-ray and radio luminosity of stellar sources called the Guedel-Benz relation and we use this to perform X-ray-radio-optical matching to find new stellar radio sources. I will present the method and results of these two search methods using ASKAP.

KEYWORDS radio astronomy, radio stars, planet habitability, ASKAP, polarisation

FM 5

#3313

Spatially Dependent Photometric Activity of M dwarfs in the Solar Cylinder

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We study the relationship between Galactic location (R, Z) and photometric activity for 3.6 million M dwarf stars within 1 kpc of the Sun. For this purpose, we identify 906 unique flare events as a proxy for magnetic activity from the SkyMapper Southern Survey DR3. We adopt vertical distance |Z| from the Galactic disc as a proxy for age and confirm a strong trend of flaring fraction decreasing with growing stellar age. Among M dwarfs within 50 pc of the Sun, we find a flaring fraction of 1-in-1,500, independent of spectral type from M2 to M7, suggesting that these stars are all in a flare-saturated young evolutionary stage. We find an unexplained kink in the slope of the overall flare fraction near 100 pc from the plane, where a steep decline begins; this slope change is visible for mid-type M dwarfs (M3--M5), suggesting it is not an artefact of mixing spectral type. Together with SDSS Hα emission, this trend is additional evidence that the activity fraction of M dwarfs depends on Galactic height and activity lifetime. While there is a hint of flattening of the overall activity fraction above |Z|~500 pc, our data do not constrain this further. Within ~500 pc distance from the Sun, we find no sign of radial disk gradients in flare activity, which may only be revealed by samples covering a larger radial range.

KEYWORDS Flare, M dwarf, Activity, Age, Statistics

FM 6

Dynamics of the ICM: Radio and X-ray Observations and Theory

Invited & Contributed Talks

FM 6

#1079

The Importance of Wideband Spectral Observations of Radio Emission in Galaxy Clusters

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It has been known for many decades that galaxy clusters host a range of radio objects which come with different physical scales and morphologies, from active and remnant radio galaxies to cluster-wide relics & haloes. Historically some of these objects have been hard to unambigously classify based on morphology alone. Furthermore, the physically interactions been different types of radio objects have often required detailed spectral and polarimetric observations to untangle, meaning assembling large statistical samples has been difficult. However, with the advent of the most recent set of radio interferometers, particularly those with wide-band spectral coverage, we have an unprecedented opportunity to classify radio objects in clusters based not on their often indistinct morphology, but on the physics that drives them. I will discuss recent work using complementary datas from LOFAR, MeerKAT, ASKAP, GMRT & the MWA to demonstrate the value of wide-band spectral observations in determining the physics of radio objects in galaxy clusters and, as a result, gain insights into the dynamical history of the clusters themselves.

KEYWORDS Galaxy Clusters, AGN, Wide-band Radio Data

FM 6
#2200

Revealing properties of non-thermal emission from galaxy clusters using the Upgraded GMRT

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Diffuse radio emission in and around galaxy clusters, termed as radio halos and relics, provide pathways to learn about the the microphysics of the intra-cluster medium (ICM). In recent years with sensitive observations at low frequencies (GHz and sub-GHz), the number of galaxy clusters with diffuse radio emission has risen significantly and the details of the morphology of these sources on sub-kiloparsec scales are revealed.

The Upgraded Giant Metrewave Radio Telescope is a Square Kilometer Array pathfinder that has enabled making sensitive images at sub-GHz frequencies of galaxy clusters and superclusters. I will provide an overview of our recent uGMRT imaging of galaxy clusters and superclusters. In particular I will focus on the imaging of the high redshift cluster El Gordo at 300 - 500 MHz, 550 - 750 MHz and 1000 - 1400 MHz.

El Gordo is a massive cluster at redshift 0.87 hosting double radio relics and a radio halo. The X-ray morphology of this cluster is like a comet with two tails. I will present the uGMRT images and the spectral index map of the diffuse radio emission. We also make a point to point comparison of radio images with X-ray images that reveals a nearly linear relation.

Using a power spectrum analysis of the X-ray image, we also studied the connection between turbulence and the radio halo in the two tails of the cluster. I will also briefly describe the data analysis pipeline c alled CAPTURE that we have developed to analyse uGMRT data and touch upon results from the imaging of a couple of other galaxy clusters and the Saraswati supercluster.

KEYWORDS non-thermal radiation, galaxy clusters, radio bservations, X-ray observations, particle acceleration mechanisms

FM 6
#2409

LOFAR observations of the Perseus Cluster

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Giant radio halos are megaparsec scale sources commonly found in massive merging galaxy clusters. The synchrotron emission from halos indicates the presence of cosmic rays and magnetic fields in the intracluster medium (ICM). The favored model for the origin of radio halos is that of cosmic rays re-accelerated by merger-induced ICM turbulence. In relaxed galaxy clusters, where the central ICM cooling time is shorter than a Hubble time, smaller radio mini-halos are found. The origin of radio mini-halos in cool-core clusters is less well understood than giant radio halos in merging systems. Furthermore, it is generally not known if cool-core clusters also host more extended radio emission, beyond the scale of the mini-halo in the cluster core. Detecting a giant radio halo in a cool-core cluster is very challenging because the bright central radio AGN, ubiquitous in cool-core clusters, easily overpowers an extended low-surface brightness component. Here we present LOFAR observations of the Perseus Cluster: the prototypical massive cool core cluster hosting the famous radio AGN 3C84, associated with the brightest cluster galaxy NGC1275, and a radio mini-halo. The sensitive high-resolution LOFAR observations present us with a spectacular new view of the Perseus Cluster, unveiling a rich variety of radio emissions that remained hidden in previous shallower studies.

KEYWORDS galaxy clusters, particle acceleration, radio emission, intracluster medium

FM 6

#1805

Galaxy clusters in the Decameter Sky

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A fraction of galaxy clusters contain bright and extended radio halos that trace the shape of the underlying intracluster medium. Due to the short lifetime of synchrotron emitting plasma and the large physical size of radio halos, this infers continuous (re-)acceleration of cosmic ray electrons. One explanation for this is given by the turbulent reacceleration model, where turbulence caused by galaxy cluster mergers accelerates electrons to relativistic energies. A critical prediction from this model is that minor mergers with lower mass clusters produce radio halos with significantly steeper spectra. To test this prediction, low-frequency radio observations are uniquely valuable. In this talk, we will report the first detection of an ultra-steep spectrum radio halo in Abell 655 in the decameter (15-30 MHz) band, using a novel calibration strategy for the LOw Frequency ARray (LOFAR). This radio halo has a steep spectral index of ~ -1.8 between 150 MHz and 15 MHz. Finally, we discuss the implications of this discovery for constraining particle reacceleration models.

KEYWORDS Radio halos, Cosmic rays, Particle Reacceleration models, Low-frequency observations, Radio Astronomy

FM 6

#2171

Tackling the complexity of non-thermal phenomena in galaxy clusters and LSS

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Cluster scale radio emission, in the form of radio halos and relics, reveals the presence of relativistic particles and magnetic fields in the ICM, their origin is a long-standing problem. Halos and relics are generally found in dynamically disturbed clusters, suggesting that a fraction of the energy associated with the hierarchical process of cluster assembly is turned into relativistic particles and magnetic fields. It requires that complex mechanisms operating in the ICM are able to transfer energy from very large, Mpc, scales to electromagnetic fluctuations on much smaller scales. More recently, LOFAR observations discovered radio emission from filaments connecting cluster pairs, radio bridges, demonstrating that non-thermal components can be generated on scales that had never been probed before. Addressing the mechanisms at the origin of these components and their interplay with the ICM is important to explore particle acceleration physics in novel regimes and the collisionless processes that govern ICM (micro-)physics.

In this talk I will discuss models of particle acceleration in galaxy cluster and LSS, and the comparison with observations from radio to gamma-rays. Specifically I will focus on ICM turbulence and turbulent acceleration and on the impact of ICM (micro-)physics on the efficiency of particle acceleration.

KEYWORDS galaxy clusters, turbulence, particle acceleration, non-thermal emission, collisionless plasma, manetic fields

FM 6
#1238

High angular resolution SZ cartography of galaxy clusters with NIKA2 at the IRAM 30-m telescope

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Up until recently, mapping the temperature and the entropy of the intracluster medium (ICM) required high signal-to-noise observations in the X-ray domain to fit spectra extracted from several independent regions of the ICM. However, as the exploration of cluster formation extends to high redshifts, the cost of these observations becomes prohibitive. It is therefore essential to develop new procedures to characterize temperature and entropy fluctuations within the ICM at high redshift in order to improve our understanding of cluster formation. In this context, high angular resolution SZ observations have a major role to play. Because of their respective dependence on the density and pressure of the ICM, the combination of X-ray and SZ observations allows us to map the temperature of the ICM without having to consider spectral information in X-ray data. With both a wide field of view (6.5 arcmin) and a high angular resolution (17.7 and 11.2 arcsec at 150 and 260 GHz), NIKA2 is a KID-based camera that has been successfully installed and commissioned at the IRAM 30-m telescope (Pico Veleta, Spain). It is a very well suited instrument to map the SZ signal of high redshift clusters up to R500.

I will present the NIKA2 SZ Large Program aiming at characterizing the ICM properties of 45 SZ-selected clusters at $0.5 < z < 0.9$ as well as recent results from two independent open time programs conducted with NIKA2 at the IRAM 30-m telescope. The first one takes advantage of the complementary of X-ray and SZ observations to map the ICM temperature of IR-detected galaxy clusters at $z > 1$ using Chandra and NIKA2 data. The second one intends to perform the first ICM temperature mapping based on the resolved detection of the rSZ effect in the massive cluster RXJ J1347–1145 from the combination of NIKA2 and MUSTANG-2 data.

KEYWORDS SZ effect, Clusters, ICM, High redshift

FM 6
#1825

The utility of subarcminute SZ observations with MUSTANG-2

Charles Romero[1]

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X-ray and SZ observations of the intracluster medium (ICM) are highly complementary. As ICM studies focus more attention on the dynamics of the ICM, the need for sub-arcminute SZ observations to complement X-ray observations becomes evident. Several SZ instruments achieve this; one such prominent instrument is MUSTANG-2, which operates at 90 GHz on the 100-m Green Bank Telescope (GBT) and achieves 9 arcsecond (FWHM) resolution with an instantaneous FOV of 4.2 arcminutes. This resolution allows us to detect shocks and "ICM cavities", probe pressure fluctuations, and detect (and remove) compact sources in galaxy clusters. We present results from MUSTANG-2 that highlight each of these capabilities.

KEYWORDS galaxies: clusters: intracluster medium

Gas thermodynamics from the SZ effects: an ACT view

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The thermodynamic properties of the ionized baryons in galaxies, groups, and clusters encode the effects of the assembly history and feedback processes that shape galaxy and cluster formation. These properties can be studied through the thermal and kinematic Sunyaev-Zel'dovich (SZ) effects imprinted on high resolution maps of the cosmic microwave background (CMB), measured for individual clusters or from stacking analyses. I will present constraints on the intracluster medium (ICM) parameters obtained from a detailed analysis of the SZ spectrum of individual clusters, using multi-band observations of the Atacama Cosmology Telescope (ACT), Planck and Herschel. I will also present recent SZ cross-correlation measurements from the ACT DR5 and Planck, from which we achieve high signal-to-noise measurements of the electron density, temperature and pressure distribution around the CMASS galaxy groups. I will discuss our constraints on the feedback and the non-thermal pressure support, as well as the effect of including baryons in the modeling of galaxy-galaxy lensing measurements. These measurements provide novel tests of current and future hydrodynamical simulations with sub-grid physics models. I will outline the rapid growth of SZ cross-correlation measurements expected over the next decade with upcoming CMB experiments, like Simons Observatory and CMB-S4, and large-scale structure surveys like DESI, the Rubin Observatory or Euclid.

KEYWORDS SZ, Galaxy clusters, ACT

FM 6

#684

Multi-wavelength view of a massive galaxy cluster merger at z=1.13

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In my talk I will present recent results from a multi-wavelength analysis of the SPT-CL J2106-5844. Among the most massive galaxy clusters ever observed at a redshift z>1, multiple studies have shown that the system is undergoing a major merger. Observations of the Sunyaev-Zeldovich (SZ) effect by the Atacama Large Millimeter Array allowed us to identify two distinct components to the intracluster medium, more or less cospatial with mass sub-structures found in the independent weak-lensing reconstruction of the cluster mass. On the other hand, pilot data from the Evolutionary Map of the Universe survey, in combination with observations by the Australia Telescope Compact Array, highlighted the presence of an extended radio structure, potentially associated with runaway cooling of gas and enhanced star formation activity within the cluster core. Although many questions are still unresolved, this study demonstrated that the inclusion of SZ information at high angular resolution into a nearly panchromatic picture of galaxy clusters can provide paramount insights into the dynamical and astrophysical processes operating in the intracluster medium at epochs central for the assembly of galaxy clusters.

KEYWORDS Sunyaev-Zeldovich effect, cluster mergers, intracluster medium, ALMA

RXC-J2014.8-2430, the strongest cool core galaxy cluster in REXCESS: How the hot intracluster medium affects the cold molecular gas in and around the brightest cluster galaxy

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ALMA has the unique capabilities to simultaneously observe the cold gas and hot thermalized intracluster medium (ICM) in distant galaxy clusters. The cold gas in galaxies is extensively studied with ALMA through low-J CO and [CII] spectral line transitions, while the (with ALMA) lesser-studied hot ICM can also be observed through the Sunyaev-Zel'dovich (SZ) effect. With ALMA having access to both media, one can directly study their interaction which is crucial in understanding the multifaceted processes that drive galaxy evolution.

In this study, we show via ALMA and ACA Band 3 CO(1-0) and SZ observations how bulk motions of the hot ICM within the cluster potential disturb the distribution of the molecular gas in and around the brightest cluster galaxy (BCG). To constrain the SZ-effect at larger radii, we jointly model the ACA and ALMA observations with observations from the Atacama Cosmology Telescope (ACT) via a Bayesian-forward modelling technique that is implemented in the Fourier-domain.

From the CO(1-0) observations, we find filamentary structures around the core of the BCG. We estimate the ram pressure of the cold molecular gas in these filaments and find similar values to the local thermal pressure of the ICM. The comparable levels of thermal and ram pressure support the idea that ram pressure due to sloshing is a factor influencing the observed spatial distribution of the cold molecular gas.

This case study indicates that the ICM plays a part in determining the fate of the cold gas and, by extension, the star-formation of cluster members. By having access to SZ-observations — through ALMA, ACA, and ACT —, we can further explore how the ICM shapes the evolution of star formation through SZ-effect and add another piece to solve the galaxy-evolution puzzle.

KEYWORDS ICM, SZ-effect, BCG, Sloshing, cold molecular gas

FM 6

#2590

Updates on Turbulence in Hot ICM

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Turbulence plays a crucial role in the hot intracluster medium (ICM). It transfers energy from large to small scales, prevents cooling and suppresses star formation, amplifies magnetic fields, and accelerates cosmic rays. Despite its importance, many questions related to ICM turbulence remain unexplored. In the light of upcoming X-ray missions with high-resolution spectral capabilities, it is timely to review what we have learned so far, the challenges we are facing in both observations and simulations, and ways to overcome them. In this talk, I will address these questions, mainly focusing on indirect probes of turbulence, discuss the limitations of these measurements and improvements with near-future direct velocity measurements.

KEYWORDS Galaxy clusters, X-rays, Turbulence

FM 6
#525

XRISM observation of galaxy clusters

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Hitomi observation of the Perseus cluster demonstrated the power of high-resolution X-ray spectroscopy as a probe of the ICM. However, observation of other galaxy clusters was not possible due to the communication loss. XRISM, the recovery mission of Hitomi, is planned to be launched in FY2022. XRISM will be equipped with two instruments, the X-ray microcalorimeter Resolve and the wide-FOV CCD Xtend. In particular, Resolve is expected to reveal various ICM properties such as motions, turbulence, composition, and physical state in full-scale beyond the Perseus cluster for the first time in the world. The XRISM PV phase target list, including several galaxy clusters, is now open, and the target team is working on the observational strategy of each target. In this presentation, we will present the expected results by the XRISM observation of galaxy clusters, mainly focusing on the PV phase targets. We will briefly summarize the current status of satellite development as well.

KEYWORDS XRISM, Resolve, clusters of galaxies, ICM

FM 6

#2045

ICM dynamics in the Coma cluster (X-ray view)

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The Coma cluster has been well covered in X-rays by SRG/eROSITA up to R200. About 10 million X-ray photons have been collected revealing many structures in the distribution of hot cluster gas that are associated with the recent accretion history of Coma. Some of these associations appear robust, while others are more speculative. Our current views on the exquisitely complicated X-ray image of Coma will be discussed.

KEYWORDS ICM, X-rays, Coma cluster

Giant Shock Waves in Galaxy Clusters

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Intracluster medium (ICM), weakly-magnetized plasma, is a key matter component of galaxy clusters confined within the gravitational potential of dark matter (DM) halos. Its detections, especially in the cluster outskirts, are one of the major goals of the next-generation X-ray and sub-mm/SZ telescopes. An interesting observational feature of the ICM is its shock structures, driven by energetic feedback, mergers, and smooth accretion. In this talk, I will discuss the formation and evolution of giant shocks on the Mpc scale in the outskirts of galaxy clusters. I will introduce the concept of runaway merger shocks, considered as promising candidates for powering radio relics in the periphery of galaxy clusters. I will present a beautiful example of the runaway shock in the Coma cluster and its X-ray, SZ, and radio signals. In general, the runaway shocks move down a steep density gradient in the ICM, helping them maintain the strength over a large distance. They eventually overtake the accretion shock at the boundary of the ICM and re-shape the gas atmospheres in the outer cluster regions. Various shocks, contact discontinuities, and turbulence are formed in this process. This picture also naturally explains the prominent radial offset between the boundaries of gas and DM halos in galaxy clusters, long noticed in the cosmological simulations.

KEYWORDS Galaxy cluster, Shock wave, X-ray, Intracluster medium

FM 6

#907

Shocks in Merging Galaxy Clusters in Cosmological Simulations

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Merger between galaxy clusters is one of the most energetic events in the universe. With energy up to ~1064 ergs, it drives shocks of Mpc scales, called merger shocks, into the intracluster medium (ICM). A substantial fraction of the energy released during merger is dissipated at shocks on the time scale of a few giga-years. Since the energy dissipation plays a key role not only for thermal processes but also nonthermal processes in the ICM, such as the production of turbulence, the amplification of magnetic fields, and the acceleration of cosmic-ray (CR) particles, it is important to understand the merger shocks. In a set of cosmological hydrodynamic simulations, we sampled twelve binary merging clusters and classified them by merger parameters such as the mass ratio and impact parameter. To describe the characteristic properties of merger shocks, we quantified the Mach number distributions on simulated merger shock surfaces and examined how the merger parameters affect the distribution. Also, we calculated the average Mach numbers, X-ray weighted Mach numbers, and CR-weighted Mach numbers of merger shocks as well as the dissipated energy flux at the shocks. We here present some of the results and compare our simulations with relevant observational data.

KEYWORDS galaxy clusters, merger shocks, intracluster medium, numerical simulation

FM 6
#2293

X-ray and radio multi-wavelength view of clusters of galaxies

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Galaxy clusters are a melting pot of baryons and are bright in X-ray wavelength resulting in the energy conversion from gravitational energy into thermal and non-thermal energies. Radio emission in galaxy clusters is closely connected with baryon physics such as AGN-feedback, shock front, and turbulence. Therefore X-ray and radio multi-wavelength study of galaxy clusters is a powerful approach to understanding the underlaying physic. In this contribution, we will introduce some important results from the multi-wavelength studies and some prospects for upcoming facilities.

KEYWORDS X-ray, radio, shock structures, motion, cold front

FM 6

#2198

A Multi-Probe Analysis of the 3-D Shapes and Non-Thermal Pressure in the CHEX-MATE Galaxy Clusters

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I will present an overview and current progress of our triaxial analysis of the CHEX-MATE galaxy clusters. CHEX-MATE is a 3 Msec XMM program to observe 118 galaxy clusters, and includes two samples selected based on Sunyaev-Zel'dovich (SZ) effect signal from the Planck survey: The Tier-1 represents a volume-limited (0.05 < z < 0.2) set of 61 galaxy clusters in the local universe and Tier-2 represents a mass-limited (M_{500} > 7.25 x 10^{14} M) set of the 61 most massive objects in the universe at z < 0.6.

We adapt the triaxial modeling package CLUMP-3D to jointly fit the multiwavelength data. The datasets include X-ray surface brightness and spectroscopic temperature maps from XMM-Newton, SZ effect maps from Planck and ground-based CMB instruments, and wide-field gravitational lensing (GL) maps from Subaru, CFHT, and other facilities. While the combined X-ray and SZ data measure the intra-cluster medium (ICM) thermodynamics and probe the line-of-sight geometry of the galaxy cluster shape, the GL data provides the mass distribution of the halo.

With this analysis, we aim to (i) obtain the distribution of three-dimensional triaxial shapes (axial ratios) to test Lambda-CDM predictions and better calibrate future cluster cosmology surveys and (ii) measure non-thermal pressure within the ICM to large radii in order to better understand the thermalization of newly accreted material and its associated impact on hydrostatic mass estimates.

KEYWORDS Galaxy cluster, Intracluster medium, Sunyaev-Zeldovich effect, XMM-Newton

FM 6

#2972

The interaction between merger-driven gas motions and AGN feedback in clusters of galaxies

John ZuHone[1]

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Many massive clusters of galaxies with cool cores host an active galactic nucleus in the central galaxy, which injects jets into the intracluster medium that inflate giant cavities that often shine in the radio. Most of these same clusters have sloshing cold fronts as seen in the X-ray, which are evidence of subsonic gas motions. In this talk, I will present a series of numerical simulations which show some initial results on what happens when AGN-driven jets and cavities encounter sloshing motions in a cluster core. Specifically, I will show how the motions naturally produce wide-angle tails and distorted cavities as seen in observations of a number of clusters, as well as how the cosmic ray content of the AGN bubbles can be transported by the gas motions to larger radii and potentially serve as the seeds for reacceleration by turbulence and/or shock fronts, producing features such as radio mini-halos and radio relics.

KEYWORDS

FM 6

#1453

Measuring cavity powers of active galactic nuclei in clusters using a hybrid X-ray/radio method

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As the intracluster medium (ICM) in galaxy clusters cools through the emission of X-ray radiation, it sinks down towards the central galaxy where it fuels the AGN. This AGN subsequently emits radio-mode feedback in the form of powerful jets of relativistic plasma which re-energize the ICM, completing the feedback cycle. Measurements of the energy injected by radio-mode feedback into the cluster environment have mostly relied on X-ray observations, which reveal cavities in the ICM excavated by the radio lobes. However, the sensitivity required to accurately constrain the dimensions of these cavities has proven to be a major limiting factor, and is the main bottleneck on high-redshift measurements. In this talk, we describe a hybrid method based on a combination of X-ray and radio observations, which aims to enhance our ability to study radio-mode feedback. We present one of the first samples of galaxy clusters observed with the International LOFAR Telescope with sub-arcsecond angular resolution at 144 MHz, and use this sample to test the hybrid method with low-frequency, high angular resolution observations for the first time. By comparing our measurements with results found in literature based on the traditional X-ray-based method, we find indications that the hybrid method can provide more reliable measurements, as the correlation with the traditional method improves with the sensitivity of the X-ray observations. This hybrid method enables radio-mode feedback to be studied at high redshifts for the first time even for large samples of clusters.

KEYWORDS large-scale structure of universe, galaxies: clusters: general, galaxies: active, radio continuum: galaxies, X-rays: galaxies: clusters

Phoenix rising from the ashes - co-existence of violent cooling and AGN feedback

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A simple theory of the structure formation predicts a huge amount of cooled ICM and massive star formation in the cluster center. X-ray observations, however, have found no such features and AGN jets launched from the central brightest cluster galaxy (BCG) are thought to be one of the possible heat sources. Only one exception is the Phoenix galaxy cluster located at the redshift of 0.596. The cluster possesses an unprecedented starburst BCG with an ultra heavy and fast-growth super-massive black hole (SMBH). Previous X-ray observations have revealed a mildly-cooled ICM in this cluster but its radial profile at the inner part has a large uncertainty due to the bright X-ray emission of the central AGN. They also have suggested the existence of X-ray cavities as indirect evidence of AGN jets, but a high resolution imaging of radio jets has never been achieved. Recently, we have performed the highest-resolution observations of the Sunyaev-Zel'dovich effect with ALMA and 18 GHz continuum with ATCA. Our observations successfully revealed that the ICM is cooling efficiently and nearly isobarically around the center at which we resolved bipolar radio lobes and candidates of newly-launched jets. Therefore, violent X-ray cooling and AGN feedback co-exist, which is completely different from the picture established in the nearby Universe. Surprisingly, the radio power is exceptionally weak compared to the cooling loss and the kinetic power estimated from the size of the X-ray cavities, raising some new mysteries on the AGN feedback scenario. This southern cluster is the best target for the Square Kilometre Array (SKA) and its precursors, with which we will obtain the deepest and finest images of this cluster and will frontier a new paradigm of the history of cluster formation and the co-evolution of the cluster, the BCG, and the SMBH. In this talk, we will also report the latest result of VLBI observation of the heart of the Phoenix.

KEYWORDS Galaxy Clusters, AGN jets, Cooling Flow, Radio Observation

FM 6
#2187

X-ray manifestations of AGN feedback, mergers and satellite accretion with the IllustrisTNG simulations

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With the cosmological magneto-hydrodynamical simulations IllustrisTNG (https://www.tng-project.org/), we are putting together ever more quantitative and plausible evidences as to the role that feedback from super massive black holes (SMBHs) can have in determining the physical properties of the gas in and around galaxies, all the way up to the mass scale of galaxy clusters. Powerful energy injections originating from the innermost regions of massive galaxies can drive 100-1000s km/s gas outflows (Nelson+2019a, Pillepich+2021) that in turn shock heat the gas within and around them (Weinberg+2017), decreasing the density (Terrazas+2020, Davies+2020) and increasing the entropy and cooling times of the gaseous haloes (Zinger+2020). In practice, according to our models, SMBH feedback strongly modulates the physical properties of the gas that determine its X-ray emission and the kinematics of the hot gas (Truong+2020, Truong+2021a,b). The same model for SMBH feedback produces the most diverse manifestations in the gas distribution, thermodynamics and kinematics: from large-scale, coherent features of overpressurized and X-ray emitting gas that impinge into the gaseous halo of simulated Milky Way- and Andromeda-like galaxies, and that are reminiscent of the eROSITA and Fermi bubbles in the Galaxy (Pillepich+2021); to pressure waves around brightest cluster galaxies that are reminiscent of the ones observed in Perseus. At the same time, the intra-halo gas is also affected by accretion events, such as satellite galaxies plunging into groups and clusters at supersonic speeds. With IllustrisTNG, we predict that such galaxies, which undergo ram pressure stripping and are often called and similar to jellyfish, frequently produce large-scale bow shocks in their surrounding intra-cluster medium (Yun+2019). I will give an overview of these simulation-based results, our attempts to connect them to future X-ray imaging and IFU observations, and introduce a new simulation suite: TNG-Cluster (co-PIs: Pillepich/Nelson), where we deliver ~350 haloes more massive than 10^14.5 Msun, including ~90 truly massive clusters (~10^15 Msun), with the same all-encompassing, full-physics IllustrisTNG model and with a baryonic mass resolution of ~10^7 Msun and ~kpc-level spatial resolution.

KEYWORDS

FM 6

#1276

Neutrinos and gamma rays from clusters of galaxies

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Cosmic rays can be accelerated to high energies by astrophysical objects embedded in clusters of galaxies or by shocks taking place in the intracluster medium. These cosmic rays are trapped within clusters, interacting with the gas and radiation permeating this environment, producing high-energy non-thermal messengers including neutrinos and gamma rays. These messengers can be observed either from individual clusters or as diffuse fluxes resulting from the whole population of these objects. While their fluxes depend on properties of the cosmic-ray emission, this contribution is guaranteed to exist, consequently constraining the parameter space available for other components that could generate them, such as some populations of astrophysical objects and the elusive dark matter. In this talk I will describe the propagation of high-energy cosmic rays in galaxy clusters considering a sample of these objects obtained from cosmological magnetohydrodynamical simulations of structure formation. I will then present estimates for the neutrino and gamma-ray fluxes from individual clusters, followed by estimates of the associated diffuse neutrino and gamma-ray fluxes. Finally, I will discuss these results within a broader astrophysical context, focussing on their importance for high-energy multi-messenger astronomy.

KEYWORDS neutrinos, gamma rays, galaxy clusters, cosmic rays, multimessenger

FM 6

#330

High-Energy Gamma-ray Production in Clusters of Galaxies

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In this work, we compute the contribution from clusters of galaxies to the diffuse gamma-ray background. Clusters of galaxies can potentially produce cosmic rays (CRs) up to very-high energies via large-scale shocks and turbulent acceleration. Due to their unique magnetic-field configuration, CRs with energy ≤ 1017 eV can be trapped within these structures over cosmological time scales, and generate secondary particles, including neutrinos and gamma rays, through interactions with the background gas and photons. We employ three-dimensional cosmological magnetohydrodynamical (MHD) simulations of structure formation to model the turbulent intergalactic medium. We use the distribution of clusters within this cosmological volume to extract the properties of this population. We propagate CRs in this environment using multi-dimensional Monte Carlo simulations across different redshifts (from z ~ 5 to z =0), considering all relevant photohadronic, photonuclear, and hadronuclear interactions. We also include the cosmological evolution of the CR sources. We have computed the flux of high-energy gamma-rays (E > 109 eV) and found that the clusters contribute to a sizable fraction of the gamma-ray flux observed by Fermi-LAT.

KEYWORDS MHD simulations, Clusters of galaxies, magnetic field, Cosmic-rays, Gamma-rays

Particle acceleration at accretion shocks around galaxy clusters

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Strong accretion shocks of M ~ 10 - 100 form around galaxy clusters, when the gas in void and filament regions accretes onto galaxy clusters. According to previous studies using cosmological simulations, those accretion shocks are energetically less important than the shocks inside clusters, including merger shocks. However, they could produce cosmic rays (CRs) of flat spectra through diffusive shock acceleration (DSA; a.k.a 1st order Fermi acceleration) owing to the high Mach number. Indeed, recent radio observations via LOFAR have provided evidence for CR electron acceleration at shocks formed by the infall of gas along filaments. The detectability at multi-wavelengths, such as radio, hard X-ray, and gamma-ray, of emissions through synchrotron, inverse Compton, and pion decay by the particles accelerated at accretion shocks have been investigated as well. In this context, we first performed a set of Particle-in-Cell (PIC) simulations to study the characteristics of cluster accretion shocks including acceleration processes. Based on the PIC simulation results, we calculated multi-wavelength emissions by CRs produced at the shocks. We discuss what we have learned through the comparison of our results with observations.

KEYWORDS shock, particle acceleration, radiation, cluster of galaxies

FM 6

#1136

Weak-lensing Study of Merging Galaxy Clusters and Probes of Dark Matter

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Merging galaxy clusters serve as powerful probes of the distinct natures of their three constituents: gas, galaxies, and dark matter. However, since we can only observe single snapshots of their Gyr-long merging processes, it is paramount to reconstruct their collision scenarios before serious interpretations are made. One of the most critical quantifies needed for this endeavor is the mass of the merging system, which is reliably measured only through weak gravitational lensing. In this talk, I will present our collaborative efforts to minimize mass biases in merging clusters, reconstruct collision scenarios, and constrain the self-interaction cross-section of dark matter based on multiwavelength observations and numerical simulations. We find that merging clusters with double radio relic clusters are particularly useful in astrophysical probes of dark matter since the shock properties are independent of those of dark matter to first order.

KEYWORDS ICM, dark matter, galaxy clusters, radio relics, shock

Weak-lensing Analysis of 30 Merging Clusters that Exhibit Radio Relics

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As the most energetic events in the universe since the Big Bang, collisions of galaxy clusters are important laboratories for understanding high-energy astrophysics and the formation and growth of the large-scale structure. Radio relics, synchrotron from charged particles accelerated in merger-induced shocks, are an indication of a recent collision. My thesis contains a weak-lensing analysis of thirty merging clusters that exhibit radio relics. I will present weak-lensing mass distributions for the most intriguing clusters and explain the merger scenarios that are devised from the multiwavelength data. I will then present a statistical analysis of the mass estimates for the population of merging clusters and provide insight into fitting the mass of unrelaxed systems.

KEYWORDS galaxy clusters, weak lensing, radio relics, merging clusters, dark matter

FM 6

#1244

Discovery of peculiar double radio relics in the merging cluster ZwCl J1447.2+2619

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Cluster mergers serve as powerful laboratories for cosmology and astrophysics. Radio relics, diffuse radio emissions found in the outskirts of merging clusters, are believed to originate from the merger shocks and thus provide a unique laboratory for plasma acceleration. Here we report the discovery of remarkable double radio relics in the merging cluster ZwCl J1447.2+2619 at z=0.376. Using multi-wavelength observations and numerical simulations, we demonstrate that the position and morphology of the double radio relics can be reproduced by a near head-on binary collision ~0.7 Gyr ago. Interestingly, the observed surface brightness ratio between the two radio relics is significantly lower from the ratio of other known double radio relic systems. We propose that this offset may arise from the difference of pre-existing cosmic-ray electrons. Our study shows that double radio relic systems are a powerful laboratory for understanding plasma acceleration when the analysis is aided with high-quality multi-wavelength observations and careful hydrodynamics simulations.

KEYWORDS Galaxy clusters, Radio continuum, X-rays, Weak-lensing analysis, Galaxies

FM 6
#2260

Magnetic field in galaxy clusters and beyond: new perspectives from low frequency observations

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In this talk, I will present how we can use low frequency (1 GHz and below) radio observations to constrain magnetic field properties in clusters of galaxies. In the last years, important discoveries have been made using data from the latest generation of radio instruments, such as LOFAR and MeerKAT. We know that magnetic fields are present on large scales in clusters of galaxies reaching intra-cluster bridges and intergalactic filaments. We also have direct probe that AGN at the centre of galaxy clusters and groups contribute to the magentization of the intra-cluster medium. I will show these recent discoveries and discuss how they impact our knowledge of the non-thermal plasma in clusters.

KEYWORDS radio observations, magnetic field, non-thermal emisison, galaxy clusters

FM 6

#277

MeerKAT's view of an interaction between intra-cluster magnetic field and blackhole jets

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Galaxy clusters are known to harbour magnetic fields, the nature of which remains unresolved. Intra-cluster magnetic fields can be observed at the density contact discontinuity formed by cool and dense plasma running into hot ambient plasma, and the discontinuity exists near the second brightest galaxy, MRC0600-399, in the merging galaxy cluster Abell 3376 (redshift 0.0461). Elongated X-ray emission in the east–west direction shows a comet-like structure that reaches the mega-parsec scale . Previous radio observations detected the bent jets from MRC 0600-399, moving in same direction as the sub-cluster, against ram pressure. Here we report radio observations of MRC 0600-399 that have 3.4 and 11 times higher resolution and sensitivity, respectively, than the previous results. In contrast to typical jets, MRC 0600-399 shows a 90-degree bend at the contact discontinuity, and the collimated jets extend over 100 kiloparsecs from the point of the bend. We see diffuse, elongated emission that we name 'double-scythe' structures. The spectral index flattens downstream of the bend point, indicating cosmic-ray re-acceleration. High-resolution numerical simulations reveal that the ordered magnetic field along the discontinuity has an important role in the change of jet direction. The morphology of the double-scythe jets is consistent with the simulations. Our results provide insights into the effect of magnetic fields on the evolution of the member galaxies and intra-cluster medium of galaxy clusters.

KEYWORDS Galaxy clusters, Abell 3376, Radio galaxy, MRC0600-399, MeerKAT

FM 6

#817

The detection of cluster magnetic fields via radio source depolarisation

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It is well known that galaxy clusters have magnetic fields, which play a key role in many astrophysical processes. However, the exact properties and origin of magnetic fields in clusters are still uncertain. Various studies using Faraday rotation of extended cluster radio sources have derived the magnetic field strength and structure in clusters. These studies often rely on various assumptions that could be circumvented when using radio sources behind clusters. At the moment, such a study can only be done statistically due to the low amount of polarised radio sources behind clusters.

In this talk, I present a large study on the depolarisation of radio sources induced by the magnetised intracluster medium, with observations of 124 massive clusters at $z<0.35$ with the Karl G. Jansky Very Large Array in full polarisation. We detected with high significance, for the first time, the imprint of cluster magnetic fields through the depolarisation of radio sources. By combining the radio observations with ancillary X-ray data from Chandra we investigate the depolarisation trend as a function of various cluster properties such as dynamical state, mass, and redshift. We find no strong difference in the depolarisation trend between sources embedded in clusters and background sources located at similar projected radii. Our findings show that the statistical depolarisation of radio sources is a good probe of cluster magnetic field parameters. Cluster members can be used for this purpose similar to background sources, because the local interaction between the radio galaxies and the intracluster medium does not strongly affect the observed depolarisation trend.

KEYWORDS magnetic fields, polarisation, intracluster medium, non-thermal radiation, observational, radio, x-ray

FM 6
#306

Substructure and patchiness in radio relics

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Radio relics track cosmological shocks propagating through the intracluster medium. High-resolution radio observations in total intensity and in polarisation have revealed complex structures on kiloparsec scales that are not well understood. In particular, the relation between the observed features and the underlying morphology of the magnetic field is not clear. In this work we use three dimensional MHD-Lagrangian simulations to study the radio emission produced by a shock wave that propagates through a turbulent medium that resembles the intracluster medium. We find that the synchrotron emission produced in a shocked turbulent medium through the diffusive shock acceleration mechanism can reproduce some of the observed features in radio relics. We additionally investigate whether a fresh injection or a re-acceleration model can reproduce the patchiness observed in the some radio relics at high frequencies. Our preliminary results show that neither the injection or re-acceleration models can reproduce this type of patchiness at high frequencies. In fact, we show that if radio relics are patchy at high frequencies, they necessarily also are at low frequencies. Finally, we will discuss future prospects for the numerical modelling of radio relics.

KEYWORDS radio relics, ICM, shock acceleration, numerical

FM 6
#968

Particle reacceleration in the pre-merging radio bridge A399-401

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The detection of diffuse synchrotron emission in numerous clusters shows the presence of cosmic rays and magnetic fields in the intracluster medium. The general consensus is that shocks and turbulence, generated during cluster merger events, are responsible for (re-)acceleration of particles to highly relativistic energies. Recently, the Low-Frequency Array (LOFAR) reached the sensitivity required to detect Mpc-scale filaments (radio bridges) between pre-merging cluster pairs for the first time. In this talk, we present new radio maps of one of these pairs, Abell 399 and Abell 401 (A399-401), from which we can study the morphology of the radio bridge and infer the origin and the mechanism behind the reacceleration of electrons. We clearly observe that the radio bridge has holes and ridges, which indicate that the radio bridge is not uniform. We also find evidence for active galactic nuclei (AGN) injecting plasma into the radio bridge, which has not been observed before in A399-401. Furthermore, by correlating the X-ray surface brightness with the radio surface brightness, we do not find significant support for the earlier proposed idea that the radio bridge originates from Fermi-II acceleration of electrons with turbulence. This indicates that we see a mixture of emission components and that AGN injection of relativistic particles in the radio bridge plays a more important role in the origin of the radio bridge than initially expected.

KEYWORDS cluster mergers, non-thermal radiation, intracluster medium, A399-401, Radio bridges, reacceleration, radio halos

FM 6
#1174

Multiphase turbulence in the ICM: the role of turbulence heating and the effect of the driving

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The intracluster medium (ICM) pervades the dark matter halo of galaxy clusters and is intimately linked to the evolution of the member galaxies through the cosmic baryon cycle. Jets driven by active galactic nuclei (AGNs), sloshing by the passage of galaxies during infall and mergers can drive turbulence in the ICM. Turbulence plays an important role in cluster thermodynamics through turbulent heating and turbulent mixing and can prevent runaway cooling in cool cores. On larger scales, it affects cluster mass measurements by providing non-thermal pressure support to the gas, causing the gas density and pressure profiles to deviate from hydrostatic equilibrium, an important assumption in cluster mass measurements.

However, current X-ray observations lack the spectral resolution to directly measure turbulent velocities in the hot ICM. The different indirect observational methods of measuring turbulence include X-ray brightness fluctuations, thermal Sunyaev Zeldovich effect (tSZ) fluctuations and velocity measurements of cold (104 K) Hα emitting filaments using integral field unit spectroscopy (IFU).

Using our idealised simulations, we have studied the effects of the amount of turbulent heating and the method of driving (incompressible solenoidal vs compressible) on different statistical properties of the ICM gas, such as its temperature and density distribution, and velocities of the hot (107 K gas) and cold (104 K) phases. We use our results to constrain the different indirect observational techniques for measuring turbulent velocities, such as X-ray brightness fluctuations, thermal Sunyaev-Zeldovich effect fluctuations, which are dependent on the density and pressure fluctuations, respectively. We also correlate the velocities of hot (107 K gas) and cold (104 K) phases which would let us recover hot phase velocities from IFU observations of the cold phase.

KEYWORDS Turbulence, Hydrodynamics, Galaxy clusters, Intracluster medium, Numerical methods

Galaxy Cluster simulations with a spectral Cosmic Ray model

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Non-thermal emission from relativistic electrons gives insight into the strength and morphology of intra-cluster magnetic fields, as well as providing powerful tracers of structure formation shocks.

Emission caused by Cosmic Ray (CR) protons on the other hand still challenges current observations and is therefore testing models of proton acceleration at intra-cluster shocks.

Large-scale simulations including the effects of CRs have been difficult to achieve and have been mainly reduced to simulating an overall energy budget, or tracing CR populations in post-processing of simulation output and has often been done for either protons or electrons.

We use an efficient on-the-fly Fokker-Planck solver to evolve distributions of CR protons and electrons within every resolution element of our simulation.

The solver accounts for CR acceleration at intra-cluster shocks, based on results of recent PIC simulations, re-acceleration due to shocks and MHD turbulence, adiabatic changes and radiative losses of electrons.

We apply this model to zoom simulations of galaxy clusters, recently used to show the evolution of the small-scale turbulent dynamo on cluster scales (Steinwandel, Böss et. al. 2021).

For these simulations we use a spectral resolution of 48 bins over 6 orders of magnitude in momentum for electrons and 12 bins over 6 orders of magnitude in momentum for protons.

In this poster I will give a brief overview of the CR model and its application to study radio relics and radio halos in galaxy clusters.

KEYWORDS Galaxy Clusters, Shocks, Cosmic Rays, Radio Relics, Radio Halos

FM 6
#3390

XMM-Newton view of the shock heating in an early merging cluster, CIZA J1358.9-4750

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Cluster merger is a significant event in the ICM dynamics and can release energies up to 1064 erg which dissipated into ICM heating, turbulence, particle acceleration, and magnetic field amplification. CIZA J1358.9-4750 is an early phase major merging cluster on the sky plane located very close (z=0.07). The 2D temperature map using XMM-Newton observation showed the existence of high temperature region (hot region) in the middle of the bridge. The 700 kpc wide region between southeast and northwest boundaries of the hot region has higher temperature and pseudo pressure compared to the cooler regions, suggesting the existence of two shocks. The southern one is more clearly seen and already reported by Kato et al. 2016., while the northern one is newly found. To evaluate their Mach number, we constructed a toy 3D merger model with overlapping shocked and un-shock components in the line of sight. The un-shocked ICM parameters were modeled by extrapolating undisturbed ICM properties of the two clusters using the opposite regions. Using normalization enhancement in the shocked region and the two-temperature fitting to the spectra, coupled with the Rankine-Hugoniot equation, we estimate the shocked ICM parameters, including density of shocked and un-shocked regions. As a result, the shocked region is estimated to have a depth of ~1 Mpc with a Mach number of ~1.3 in the southeast shock and ~1.7 in the northwest shock. By calculating the shock speed, the age of the shock waves is ~360 Myr. This 3D toy model is consistent with the SZ signal using Planck observation within the CMB fluctuations. Total ICM kinetic energy flow through the southeast shock was estimated to be ~2.2 × 1042 erg s-1. Assuming 10 % of this energy is converted into ICM turbulence, the line-of-sight velocity dispersion is calculated to be ~ 200 km s-1 (1 sigma), which is detectable with the XRISM mission.

KEYWORDS galaxies: clusters: individual (CIZA J1358.9-4750), galaxics: clusters: intracluster medium, shock waves, radiation: dynamics, radiation mechanisms: thermal, methods: data analysis

FM 6

#3029

A multi-wavelength study of a double radio-relic system merging along a large-scale filament

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Radio relics in merging galaxy clusters are believed to trace the locations of merger-driven shock fronts. Although every merger is in principle expected to generate two shocks propagating outward along the merger axis, it has been reported that there are a dozen or so galaxy clusters possessing two observable radio relics on opposite sides to date. Despite their rarity, double radio-relic clusters have attracted increasing attention because of their constraining power on the dynamical stage and geometry of mergers. We present a multi-wavelength analysis of the double radio-relic cluster A1240 ($z = 0.195$) and its companion A1237 ($z = 0.194$). Our weak-lensing measurements from Subaru optical imaging find that A1240 is a binary merger consisting of northern and southern mass clumps, well bracketed by the radio relics, with about 2:1 mass ratio. The mass distribution of A1240 resembles the cluster galaxy distribution and is elongated along the merger axis inferred from the orientation of the radio relics. The Chandra X-ray emission, mostly confined between the two mass clumps, is stretched in the same orientation as the mass and cluster galaxies. In addition, a third mass clump, ~1.5 Mpc south of the southern clump, coincides with A1237 and is connected with A1240 by a bridge seen in both the galaxy overdensity and mass reconstruction. Our multi-wavelength analysis reveals that the three mass clumps form an ~4 Mpc filamentary structure aligned with the elongation of the intracluster medium and galaxies. With the SDSS DR16 data analysis, we discover that A1240 and A1237 are embedded within a much larger filamentary structure whose orientation is aligned with the merger axis of A1240.

KEYWORDS Radio continuum emission, Weak gravitational lensing, Dark matter, Cosmic web, Galaxy clusters, Intracluster medium

FM 6
#2584

Simulating jellyfish features with a gas-rich dwarf galaxy

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We investigate the formation process of jellyfish galaxies using radiation-hydrodynamic simulations of gas-rich dwarf galaxies with a multi-phase interstellar medium (ISM). We place a dwarf galaxy of $M_{\star}\sim2\times10^{9}M_{\odot}$ with an initial HI-to-stellar mass fraction of 2.5 at the center of a simulation box and impose the intracluster medium (ICM) winds mimicking the strong ram pressure that galaxies can undergo at the cluster center. We find that the ram-pressure-stripped (RPS) ISM is the dominant source of molecular clumps in the near wake within 10 kpc from the galactic mid-plane, while in-situ formation via cooling is the major channel for dense gas in the distant tail of the gas-rich galaxy. Only 20% of the molecular clumps in the near wake originate from the ICM; however, the fraction reaches 50% in the clumps located at 80kpc from the galactic center since the ISM-ICM mixing forms a large amount of tail ionized gas with a short cooling time scale (<10 Myr). The tail region exhibits a star formation rate of 0.001-0.01$M_{\odot}yr^{-1}$, and most of the tail stars are born in the stripped wake within 10 kpc from the galactic plane. These stars induce bright Hα blobs in the tail. We also find that the stripped tails have intermediate X-ray to Hα surface brightness ratios ($F_X/F_{H\alpha}\sim1.5$-20), compared to the ISM (<1.5) or pure ICM (>>20). The X-ray to Hα surface brightness ratios are consistent with those observed from jellyfish galaxies. Our results suggest that jellyfish features emerge when the ISM from gas-rich galaxies is stripped by strong ram pressure, mixes with the ICM, and enhances the cooling in the tail.

KEYWORDS Galaxy environment, Ram pressure stripped tail, ICM, Hydrodynamic simulations

FM 6
#1642

Non-thermal emission from head-tail galaxy in three-dimensional magnetohydrodynamic simulations

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Head-tail galaxies are generally associated with the galaxy cluster and possess distorted radio morphology due to the strong interaction between the jets and the intra-cluster medium (ICM). The turbulence driven by the jet activity plays an important role in the re-acceleration of cosmic-ray electrons (CRe) and protons (CRp). Recent low-frequency radio observations have reported indirect evidence of re-acceleration phenomena supplied by head-tail galaxies. However, the detailed process of CRe re-acceleration in a head-tile galaxy is still poorly understood.

We present a 3D magnetohydrodynamic simulation of radio jets that interact with a steady wind. Our simulation can follow the evolution of CRe and CRp including second-order Fermi re-acceleration in turbulent flows. To model the re-acceleration process, we assume that ten percent of the dissipation energy goes to the total CR particles energy. The jet becomes sub-sonic after the bend, and jet material is mixed with wind matter due to the development of hydrodynamical instability at the velocity shear layer. Thanks to using a high-order scheme, our model successfully reproduces the collimated synchrotron threads, which are seen in recent radio observations. We find that the model without re-acceleration shows that the radio flux and spectral index respectively decrease and become steep monotonically along the tail. In this poster, we also report the spectral index and radio intensity map for models with re-acceleration. In addition, we discuss the detection possibilities of the gamma-ray emissions produced by the hadronic process from the head-tail galaxy

KEYWORDS Cluster, Jet, Radio, Cosmic-ray

FM 6

#804

Turbulent Re-acceleration Scenario for Radio Halos and High-energy Emission from Galaxy Clusters

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Some of the galaxy clusters (GCs) are found with extended radio emission, which provides evidence for the existence of magnetic fields and CR electrons in the intra-cluster medium. It has been believed that turbulent re-acceleration plays an important role to drive the radio halo (RH) emission. We study the re-acceleration of cosmic-ray (CR) protons and electrons in detail by numerically solving the Fokker–Planck (FP) equation, and show how radio and gamma-ray observations can be used to constrain CR distributions and resulting emission. Two scenarios for the origin of seed electrons for re-acceleration are compared: the secondary scenario, where they originate as secondaries of the pp collision, and the primary scenario, where the secondary population is subdominant.

First, we model the RH in the Coma cluster. We take into account the radial diffusion of CRs and follow the time evolution of their one-dimensional distribution, by which we investigate the radial profile of the CR injection that is consistent with the observed RH surface brightness. We find that the required injection profile is nontrivial, depending on whether CR electrons have a primary or secondary origin (Nishiwaki et al., 2021, ApJ, 922,190).

Next, we examine the occurrence of radio halos in the merger history of GCs. Our FP equation is used to study the lifetime of radio emission. Considering the observed fraction of RHs and the merger rate inferred from the cosmological simulations, we investigate the condition for the RH onset. We find that the RH lifetime largely depends on the seed origin, as it could be longer than the cosmological timescale in the secondary scenario. In this case, RHs should be driven by rare major mergers. In the primary scenario, however, the lifetime is much shorter and RHs should be driven by frequent minor mergers (Nishiwaki & Asano, 2022, ApJ submitted).

Finally, we evaluate the high-energy multi-messenger emission from GCs, considering the above constraints from RH observations. In a rough estimate using the typical flux and source density of Coma-like clusters, we find that galaxy clusters can make a sizable contribution to the all-sky neutrino intensity in both scenarios. In the talk, we will present the update of this estimate, where we discuss the luminosity function of high-energy emission constrained from RH observations.

KEYWORDS galaxy clusters, radio halo, cosmic rays, neutrino

FM 6
#1189

Constraints on the collisionless dynamo during galaxy cluster evolution

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Radio observations indicate the presence of microgauss-order magnetic fields in the intracluster medium (ICM) of galaxy clusters (GCs). Presumably, those fields have been amplified from primordial seed fields over several orders of magnitude during the merging events of GCs formation. However, we lack a well-posed set of theoretical equations that describe the dynamics of the ICM plasma. Indeed, the virial temperature reached by the ICM gas after a major merging event is of the order of a few keV, making the plasma weakly collisional. Therefore, an approach based on fluid equations matching the conditions of classical MHD is not justified. Furthermore, microscale instabilities (firehose and mirror) driven by pressure anisotropies with respect to the direction of the local magnetic field make the plasma highly unstable and classical dynamo processes, such as the small-scale dynamo, have to be (at least) modified, if not discarded. Ultimately, scale separation between the typical length scales at which the microscale instabilities operate and the magnetic field is amplified is required. This last condition allows us to consider semi-analytical models of magnetic field amplification, only for initial magnetic fields from between 2 and 3 orders of magnitude below the equipartition energy value with the turbulent velocity field. Therefore, a collisionless dynamo theory based of a full kinetic treatment of the Vlasov equation is required, which is far from being solved, both analytically and numerically. The aim of my work is to estimate the evolution of different plasma parameters, using Merger Tree algorithms based on the Press and Schechter formalism, in order to highlight the different characteristics of the collisionless dynamo that (hypothetically) operates during the formation of a galaxy cluster.

KEYWORDS galaxy clusters, collisionless dynamo, Intracluster medium (ICM), magnetic fields

FM 6

#780

Massive Molecular Gas as a Fuel Tank for Active Galactic Nuclei Feedback In Central Cluster Galaxies

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Massive molecular gas has been discovered in giant elliptical galaxies at the centers of galaxy clusters. To reveal its role in active galactic nucleus (AGN) feedback in those galaxies, we construct a semianalytical model of gas circulation. This model especially focuses on the massive molecular gas (interstellar cold gas on a scale of ~10 kpc) and the circumnuclear disk ($\lesssim$0.5 kpc). We consider the destruction of the interstellar cold gas by star formation and the gravitational instability for the circumnuclear disk. Our model can reproduce the basic properties of the interstellar cold gas and the circumnuclear disk, such as their masses. We also find that the circumnuclear disk tends to stay at the boundary between stable and unstable states. This works as an "adjusting valve" that regulates mass accretion toward the supermassive black hole. On the other hand, the interstellar cold gas serves as a "fuel tank" in the AGN feedback. Even if the cooling of the galactic hot gas is prevented, the interstellar cold gas can sustain the AGN activity for $\gtrsim$0.5 Gyr. We also confirm that the small entropy of hot gas ($\lesssim$30 keV cm2) or the short cooling time ($\lesssim$1 Gyr) is a critical condition for the existence of massive amounts of molecular gas in the galaxy. The dissipation time of the interstellar cold gas may be related to the critical cooling time. The galaxy behavior is described by a simple relation among the disk stability, the cloud dissipation time, and the gas cooling rate.

KEYWORDS Active galactic nuclei, Brightest cluster galaxies, Galaxy clusters, Interstellar medium, Molecular clouds

FM 6

#656

Heating particles by kinetic turbulence in the intracluster medium

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In the hierarchical formation of the large-scale structure of the universe, clusters of galaxies grow through successive mergers of subclumps, and at the same time the intracluster medium heats up to a few to several keV. A part of the energy released by mergers is converted into heat at shocks, such as merger shocks observed in radio relics. However, the majority is dissipated through the turbulence that is produced during the merging process. In this context, we studied the heatings of ions and electrons by kinetic turbulence using 2D Particle-in-Cell simulations. We confirm that the turbulence energy preferentially goes to ions, and hence a large thermal disequilibration of ions and electrons appears, qualitatively agreeing with previous works. We examine the limitation of the current picture for the kinetic turbulent heating, and suggest a scenario which may lead to the equilibrium between the ion and electron temperatures.

KEYWORDS intracluster medium, turbulence, kinetic processes

e-Talks

FM 6

#3218

Investigation of the magnetic field in filaments of galaxies using Faraday rotation measure

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Cosmic magnetism is one of the key aspects that would define the evolution of the large-scale structure (LSS) of the universe. However, many of the properties of the magnetic field in the cosmic web still remain unconstrained; outstanding examples include the strength and geometry of the magnetic field in filaments of galaxies. We study the Faraday rotation measure (RM) of the filament magnetic field using the data of LSS formation simulations. Various modelings of the magnetic field as well as its redshift dependence and the intrinsic RM of radio sources are considered. We estimate the statistical properties of simulated RMs, such as the structure functions (SFs) for small angular separations, and compare them with available observations, that is, the RMs of the NRAO VLA Sky Survey (NVSS) and LOFAR Two-Metre Sky Survey (LoTSS). We present the results and discuss the implications of our work.

KEYWORDS Rotation measure, ICM, Filament, Magnetic field

FM 6
#1829

The Missing Last Piece in the Study of ICM Dynamics and Thermodynamics

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So far, galaxies and the ICM were long believed to evolve separately. However, as revealed via our observational studies over the past 2 decades [1-4] and confirmed by numerical studies [5], these two major baryonic components of a cluster do interact with each other. In fact, gaseous components of a moving galaxy are subject to ram-pressure stripping or displacements by the ICM, and the displaced gases gravitationally pull the galaxy's stellar and Dark Matter components. As a result, a fair fraction of the dynamical energy of moving galaxies will be deposited onto the ICM on cosmological time scales. By properly considering this "missing last piece", and invoking a magnetosphere of a cD galaxy [1], we can consistently solve the following puzzles with the ICM. (i) The view provides a straightforward explanation to the well-known fact about nearby clusters; galaxies are most concentrated whereas the ICM is most extended. (ii) The energy deposited onto the ICM is just sufficient to suppress Cooling Flows [1,4]. (iii) The reaction from the ICM can explain the observed cosmological in-fall of galaxies towards the centers of their host clusters [2,3]. (iv)This view provides a natural account for the presence of a large amount of metals in the ICM, and the very uniform ICM metallicity up to the cluster periphery. (v) An explanation is also given to the observed stable co-existence of cool and hot ICM components in the cluster core. (vi) The very mild ICM turbulence, measured with Hitomi in the core of Perseus cluster [6], can be reproduced [4]. (vii) A natural solution is given to the widely known "environmental effects", both spatially and evolutionarily. (viii) The "excess entropy" problem may also be solved.

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KEYWORDS ICM heating, turbulence, ram pressure stripping, galaxy infall

FM 6

#1796

Constraints on the Thermodynamic State of X-Ray Bubbles in MS0735 with MUSTANG-2

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We report on the detection of two cavities or bubbles in the intracluster medium of the galaxy cluster MS 0735.6+7421 that were formed by the action of relativistic jets sourced by an active galactic nucleus. Using the MUSTANG-2 instrument on the Green Bank Telescope, we measure the suppression of the Sunyaev-Zeldovich effect signal within the cavities, and from that suppression we infer the thermodynamic state within the cavities. We find that the suppression of the signal within the cavities is inconsistent with thermal support by electrons with temperatures less than 100 keV.

KEYWORDS Galaxy Clusters, ICM, Jets, AGN, X-ray Cavity

FM 6

#1115

Probing the magnetized intracluster medium (ICM) with synchrotron keys

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Observations of Faraday rotation measure (RM) of polarized radio sources located either inside or behind galaxy clusters suggest that the intracluster medium (ICM) is magnetized. The observed fields are of micro Gauss strength and correlated on several kilo-parsec scales. 'Fluctuation' dynamos

appear to be ideally suited for amplifying dynamically insignificant seed magnetic fields to observable strengths. The fields produced due to such dynamo action are spatially intermittent with a non-Gaussian distribution. While Faraday RM provides information about the line-of-sight (LOS) component of the magnetic field, synchrotron emission and its polarization are the other two complimentary observables that furnish information about the magnetic field in the plane of sky. Aided by high resolution numerical simulations of fluctuation dynamos, I will discuss certain key results on the properties of polarized synchrotron emission and the role that Faraday rotation plays in inferring the polarized structures in the ICM. In particular, some of the prime issues that I intend to address concerns the Faraday depth (FD), how can one relate the power spectrum of FD to that of the magnetic field, the statistical nature of the total and polarized synchrotron emission and how these are affected by frequency dependent Faraday depolarization. Further, I will also discuss the effects of different turbulent driving scales on the properties of the polarized emission and how observations of the polarization fraction can be used to gain crucial insights on the turbulent driving scales in the ICM. The results from our study underlines the need for high frequency observations ($\geq$ 5 GHz) to detect polarization in cluster radio halos and with high spatial resolution ($\approx$ 1 kpc) to effectively probe the properties of polarized emission in the ICM.

KEYWORDS Galaxy clusters, intracluster magnetic fields, magnetohydrodynamic simulations, Dynamos, Polarization, Depolarization

FM 6

#835

Mass-Velocity Dispersion Relation on BCG-Cluster Scales

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We investigate a kinematic scaling relation between the baryonic mass and the flat velocity dispersion, i.e., mass-velocity dispersion relation (MVDR), from the brightest cluster galaxies (BCGs) to the galaxy clusters. In the BCG samples, the baryonic mass is mainly dominated by the stellar mass while the velocity dispersion profiles are explored with the integrated field unit by Mapping Nearby Galaxies at Apache Point Observatory (MaNGA). As for galaxy clusters, the baryonic mass is majorly estimated by the gas mass while the velocity dispersion profiles are measured with member galaxies in the HIghest X-ray FLUx Galaxy Cluster Sample (HIFLUGCS). For the first time, we reveal a tight empirical relation on BCG-cluster scales, i.e., log(Mbar/MΘ)=(4.1±0.1)log(σlos/km/s)+(1.6±0.3), with a tiny lognormal intrinsic scatter of 10%. This slope is consistent with the implication of the acceleration relation in galaxy clusters, which is reminiscent of the spiral galaxies, albeit at a larger characteristic acceleration scale. Additionally, the flat velocity dispersion is presented in both BCG and cluster samples. Besides, the residuals of the MVDR represent a Gaussian distribution, displaying no correlations with four properties: baryonic mass, scale length, surface density, and redshift. Notably, the MVDR on BCG-cluster scales provides a strict test, which disfavors the general prediction of the slope of three in the dark matter model.

KEYWORDS Intracluster medium, Dark matter, Galaxy clusters, Brightest cluster galaxies, X-ray astronomy, Kinematics

Magnetized ICM filaments and radio jet interactions

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The central region of the poor cluster Abell 194 is filled with a dense network of filamentary synchrotron features. A pair of prominent narrow filaments wrap around a bend in the northern jet of 3C40B and extend over 200 kpc from that intersection. The narrow filaments are embedded in a thick 300 kpc long cocoon. The structure of the filaments and their spectral behavior suggest that they have been stretched by their interaction with the jet, amplifying the magnetic fields and pumping energy into the relativistic electron population. A 35 kpc diameter X-ray cavity surrounds the structure, implying that the pressure from magnetic fields and relativistic particles was able to exclude the hot gas from this region. The Faraday structure appears dominated by variations in the distance of features along the line of sight, instead of unrelated foreground fluctuations. This allows a (limited) reconstruction of the 3D structure of the jets, filaments and lobes of 3C40B. We present these as movies showing their appearance from different viewing angles.

KEYWORDS ICM, Magnetic, jets, Filaments, Faraday, Clusters

FM 6

#510

Slee et al.'s four extreme relic radio sources revisited

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We will present new high-resolution, high sensitivity results of four relic radio sources in the Abell clusters A13, A85, A133 and A4038 (Slee et al. 2001) at the angular resolutions of 2-5 arcsec from 1450 MHz to 250 MHz bands of the upgraded Giant Metrewave Radio Telescope. We supplement our uGMRT observations with results from MeerKAT 870-1712 MHz data (Knowles et al. 2022) and 'classic' GMRT data. The main goal is to explore whether the unprecedented 0.1-0.005 mJy sensitivity in the large frequency range 250--1712 MHz at the resolution of a few arcsecond reveals new features in the radio emission which might have been missed in radio observtaions of relic radio sources. Indeed, our deep images show a remarkable variety of fine structure, e.g., arcs, loops, plumes, ribbons and wisps. Additional observational data for these clusters, culled from the Chandra archive, identify erroneous pieces of information. We will present first results for these four sources, more specifically, quantitative results about their nature, dynamics and energetics.

KEYWORDS Active galactic nuclei, Galaxy clusters, Intracluster medium, Radio continuum emission, Radio galaxies, Tailed radio galaxies, X-ray active galactic nuclei

Soft X-ray spectral analysis and black hole mass determination of Mrk 273

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Dynamics of intracluster medium of galaxy clusters is determined by masses of galaxies and dark matter halos in it. Groups and pairs of galaxies are also examples of complexes with similar structure. In this work we performed a new estimation of central black hole mass in binary AGN Mrk 273. This object is one of the nearest Ultra-Luminous Infrared Galaxy (ULIRG) at a distance of about 176 Mpc and is a good laboratory to investigate the effects of dual AGN activity. The low-energy spectrum of ULIRGs is dominated by a thermal plasma component with temperature kT ~ 0.7 keV. A systematic analysis of the soft X-ray emission 0.1-2 keV from Mrk 273 was carried out by combining 5 observations with the ACIS-S camera from the Chandra data with the total observation time of 200 kiloseconds for the Southwest nucleus. The Northeast nucleus is consistent with a heavily absorbed AGN at a projected distance of 0.75 kpc from the Southwest nucleus. We used a bulk-motion Comptonization model for soft excess which is in general applicable to any physical system powered by accretion onto a compact object, and assumes that soft seed photons are efficiently up-scattered via inverse Compton scattering in a hot and dense electron corona. The main model parameters are the characteristic black-body temperature of the soft photon source and a spectral energy index which characterize the Comptonized spectrum power law shape. We assume, with some restrictions, the existence of similar states of activity identified in supermassive and stellar mass black holes and used the scheme for black hole binaries of the accretion flow in different spectral states as a function of the total Eddington-scaled mass accretion rate m. As a result we obtained a value of SW nucleus black hole mass 293±177 millions of Solar mass, which is the first estimate of the mass of this nucleus at the time. Applied method allows to find black hole mass in non-obscured AGN directly from X-ray observations.

KEYWORDS X-ray sources, active galactic nuclei, binary black holes

FM 6

#246

Reacceleration of Preexisting Suprathermal Electrons nin Weak ICM Shocks

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Recent studies have shown that thermal electrons can be preaccelerated and injected into diffusive shock acceleration (DSA) only in supercritical (M_s>2.3) quasi-perpendicular shocks in the high-β ICM, owing to various microinstabilities that generate scattering waves on multiscales. In this work, using 2D particle-in-cell simulations, we explore the feasibility that preexisting suprathermal electrons can facilitate electron injection by enhancing the excitation of those microinstabilities even at subcritical ICM shocks. We find that the presence of preexisting suprathermal electrons can increase the electron reflection at the shock ramp, which results in the enhanced parallel temperature anisotropy in the upstream region. This leads to the enhancement of the Fermi-like acceleration mediated by the electron firehose instability in the shock upstream. However, preexisting suprathermal electrons do not boost the excitation of the Alfven ion cyclotron instability, which generates multiscale waves from electron to ion scales in the shock transition zone. As a result, they do not aid electron injection to DSA at subcritical ICM shocks. This calls for other ingredients such as preexisting turbulence on relevant kinetic scales in the ICM in order to explain the origin of radio relics with subcritical shocks.

KEYWORDS Shock, cosmic rays, radio relics, ICM

Astronomy for All
Busan 2022

FM 7

Astrometry for 21st Century Astronomy

Invited & Contributed Talks

FM 7

#943

21st Century Astrometry and its Science Applications

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Dramatic advances in astronomical instrumentation and data processing power have transformed astrometry, over the last decades, from a narrow specialist field into a powerful standard tool for astronomical research. In the optical regime Gaia is the prime example of this, but parallel developments are happening in ground-based techniques and at other wavelengths. In this talk I outline some of the advances that have enabled this transformation and give examples from the amazingly rich variety of science applications of modern astrometry. Many more examples are given elsewhere at this meeting. It is clear that we have only seen the beginning of this process: Gaia has yet to demonstrate the full extent of its capabilities and will be much expanded in depth and scope by other projects, the full synergies of which may only become apparent much later. The review ends with a few reflections on the long-term prospects and challenges of astrometry.

KEYWORDS astrometry, instruments, parallaxes, proper motions, space

FM 7

#2135

The 21st Century Challenge of Distances: More Robust, Faster, and Farther

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Distances are essential to Astronomy to convert observed quantities (e.g., angular size or apparent luminosity) to physical quantities, the latter being what is ultimately vital to better describing the processes in the Universe. Within the Hubble Flow, the conversion between distance and redshift provides a means to determine distances. Interior to the Hubble Flow, the utilizing key stellar populations that serve as standard candles remains the best means of determining distances. Prior to Gaia, however, only certain sub-types of standard candles could be calibrated using trigonometric parallaxes and, even then, the calibrations did not fully marginalize over the key aspects that govern stars (e.g., mass/age, chemical composition) to properly understand population-level effects. The parallaxes provided by Gaia provide access to much broader swaths of the Hertzsprung-Russell diagram, which allow stellar astronomers to produce more robust calibrations for standard candles, as well as to better utilize statistical techniques. In this talk, I will articulate how pressing 21st century challenges in astronomy can be addressed directly as we are able measure distances faster (more efficiently) and to larger distances thanks to broader access to stellar populations.

KEYWORDS Astrometry, Distances, Stellar Populations, Extragalactic Distance Scale, Galactic Distance Scale, Standard Candle

FM 7

#2847

The Fifth Catalogue of Nearby Stars (CNS5): catalogue construction, completeness, and luminosity functions

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Nearby stars are key objects for numerous research tasks, ranging from target selection for exoplanet surveys to testing stellar evolution models and studying the composition of the Galactic disc. The CNS5 provides a volume-limited sample of all known stars which are possibly located within 25 pc from the Sun. Here we discuss our approach to construct an astrometrically clean catalogue of nearby stars based on \textit{Gaia}~EDR3, \textsc{Hipparcos}, complemented with parallaxes from ground-based astrometric surveys carried out in the near-infrared. In particular, we describe how we removed sources with spurious astrometric solutions in \textit{Gaia}~EDR3 with a method based solely on astrometry, so that the photometric parameters themselves are not involved in the selection process.

We assess the CNS5 completeness using a Kolmogorov-Smirnov test and derive observational luminosity functions for the main-sequence stars and white dwarfs in the solar neighbourhood.

KEYWORDS astrometry, solar neighbourhood, stellar content, Gaia, parallax, luminosity function, catalogue completeness

FM 7
#1050

The Galactic 3D large-scale Distribution of Dust from Astrometric Data

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The Galactic 3D dust distribution is highly relevant for many processes in the interstellar medium as well as for correcting astronomical observations for its absorption and emission at many wavebands of the electromagnetic spectrum. However, inherently we observe only a projection of the sky on Earth without distance information. Astrometric data, such as parallax measurements to stars by Gaia and extinction data from spectroscopic measurements, is crucial in de-projecting our 2D view to 3D. Here, we aim for a 3D reconstruction of the Galactic dust distribution at a significantly higher resolution orders of magnitude above previous reconstructions. We use iterative grid refinement to take advantage of the spatial correlation structure in our log-normal process for the dust density. Our map is informed through 111 Million data points, combining data of Gaia DR2, PANSTARRS, 2MASS, and ALLWISE. The log-normal process is discretized to 122 Billion degrees of freedom. We derive the most probable posterior map and an uncertainty estimate using natural gradient descent and the Fisher-Laplace approximation. The dust reconstruction covers a quarter of the volume of our Galaxy, with a maximum coordinate distance of 16 kpc and meaningful information up to 4 kpc at an angular grid resolution of about 2'.

KEYWORDS Cartography, Applied Astrometrics, Interstellar Medium, Bayesian Modeling, Big Data

Galactic Planetary Nebulae central stars properties and binarity from Gaia EDR3 astrometry and photometry

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Gaia Early Data Release 3 (EDR3), published in December 2020, features improved photometry and astrometry compared to that published in the previous DR2 file and includes a substantially larger number of sources, of the order of 2,000 million, making it a paradigm of big data astronomy. Many of the central stars of planetary nebulae (CSPNe) are inherently faint and difficult to identify within the field of the nebula itself. Gaia measurements may be relevant not only in identifying the ionizing source of each nebula but also in the study of their physical and evolutionary properties.

We present a catalog of 2035 PNe with their corresponding CS identification from among Gaia EDR3 sources. We obtain the distances for those with known parallaxes in EDR3 (1725 PNe). In addition, for a sub-sample (405 PNe) with the most accurate distances, we obtain different nebular properties such as their Galactic distribution, radius, kinematic age, and morphology. Furthermore, for a set of 74 CSPNe, we present the evolutionary state (mass and age) derived from their luminosities and effective temperatures from evolutionary models. Finally, we highlight the detection of several wide binary CSPNe through an analysis of the EDR3 astrometric parameters, and we contribute to shedding some light on the relevance of close binarity in CSPNe.

KEYWORDS planetary nebulae, stars:distances, astrometry: binaries, star:evolution

FM 7
#2117

The stellar streams revolution with Gaia

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The astrometric data from the Gaia satellite unleashed in the last few years a series of results on stellar streams in the Milky Way. Before Gaia data, the detection and studies of tidal streams were extremely challenging due to their low surface brightness. The spectroscopic follow-up in turn was very difficult as stream stars were smamped by foreground contamination. With accurate astrometric data from Gaia however the streams clearly light up in phase-space, allowing both efficient detection, and spectroscopic follow-up of stream stars. This lead to many exciting results, like the discoveries of large number of streams by the STREAMFINDER collaboration, detection of stream perturbations in nearby streams like GD-1 and others. That also enabled projects like S5 (Southern Stellar Streams Spectroscopic Surveys) that have been observing hundreds of stars in stellar streams and allowed us to create a 6-d phase-space map of many of these structures as well as constrain their stellar populations. The data from S5 in combination with the data from Gaia allows us to probe the intricacies of interactions of the Milky Way and the Magellanic Clouds by analysing streams like Orphan-Chenab. With S5-like data we are also able to detect stream perturbations in more distant streams compared to previously studied ones that are more likely to be caused by the dark matter subhalos. Finally, the astrometry from Gaia and future astrometric missions will be essential for the spectroscopic follow-up of stellar streams and other accreted substructures in the halo with upcoming large spectroscopic surveys like 4MOST, WEAVE, MSE and others.

KEYWORDS stellar stream, gaia, astrometry, milky way

FM 7

#2993

The Gaia mission and the Solar System: new perspectives

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Gaia has an important impact on Solar System studies, under many aspects. Data Release 2 already, revealed the interest of the accurate asteroid astrometry and photometry for several applications, ranging from the derivation of rotation periods to orbit improvement. Also, the accurate positions for the stars and the observed asteroids have permitted an unprecedented increase in efficiency of the observation of stellar occultations, that in turn, can produce Gaia-level astrometry and give access to physical properties. The importance of Gaia for asteroid science is dramatically amplified by the recent Data Release 3, expanding the number of asteroids (from 14,099 to more than 152,000) and the time span of the observations (nearly 3 years). In this talk, we will review the main properties of Solar System data in DR3, and illustrate the first applications and findings, such as the astrometric signature of asteroid satellites. This is probably present as a mas-level wobbling of the astrometry for several small <10 km asteroids, accessible to measurements for the first time with Gaia. We will also discuss the detection of the Yarkovsky effect and show how the knowledge of shape is relevant for the best exploitaiton of Gaia astrometry for large (>20-30 km) asteroids. The importance of coupling astrometric data with photometry and reflectance spectra (provided for 60,000 asteroids in DR3) will be discussed.

KEYWORDS asteroids, astrometry, Gaia mission, Solar System

The velocity distribution of white dwarfs in Gaia EDR3

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There are ~1.5 billion sources with parallaxes and proper motions in Gaia EDR3. When investigating velocity distributions of stars, one typically combines this with radial velocity measurements to give a full 3D velocity. As Gaia currently has ~7.2 million sources with radial velocities, this leaves only ~0.5% of sources which one can typically use. The wealth of information locked within the remaining ~99.5% cannot be overstated.

However, with a distribution of stars widely spread across the sky we can statistically estimate its velocity distribution using a maximum likelihood approach and just the parallaxes and proper motions. By removing the need for radial velocities, we can can investigate the kinematics of different populations previously unavailable for such studies. One such population are white dwarfs and in this work, we use a large sample of ~130 000 white dwarfs in Gaia EDR3 and find the velocity distribution and dynamics of several sub-samples within different brightness and colour cuts.

The velocity distribution of nearby white dwarfs has never been determined using such a large sample. We may learn more about the Solar neighbourhood from how this distribution differs from that of main sequence stars. Interestingly the Colour-Magnitude diagram of white dwarfs from Gaia DR2 revealed a bifurcation, the cause of which is an active topic of research. The second sequence is attributed to a mix of high-mass H-dominated and lower-mass He-dominated WDs. Higher mass WDs will have lived shorter lives and show less dynamical heating than their low-mass counterparts and so can be distinguished through their kinematics. In our work, we investigate these kinematics and velocity distribution of the WDs as a whole as well as in the two separate sequences to provide further insight into these populations.

KEYWORDS Velocity distribution, Gaia EDR3, White dwarfs, solar neighbourhood, stellar kinematics, Galactic structure, Statistical methods

FM 7

#1032

Measuring masses of dark lenses with astrometric microlensing with Gaia

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Gaia is revolutionising many fields of astronomy with its superb data. However, its data's full potential is yet to be explored, in particular in the form of the astrometric time-series with sub-mas accuracy. This unique data product of Gaia not only provides measurements of parallaxes and proper motions of billions of stars but can also help detect tiny displacements caused by microlensing of the background stars by foreground lenses. The combination of Gaia astrometry with Gaia and ground-based photometry of microlensing events will yield mass measurements for hundreds of lenses, in particular for dark lenses such as galactic black holes. I will present the status of Gaia microlensing studies of dark lenses based on the Gaia DR3 microlensing catalogue and events found by the Gaia Science Alerts. I will also show simulations of Gaia astrometric microlensing events and discuss the prospects of microlensing studies with Gaia DR4.

KEYWORDS Gaia, microlensing, black holes, astrometry

FM 7

#1568

The Astrometric Animation of Water Masers towards the Mira Variable BX Cam

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We report the observational results of water (H2O) masers around the Mira variable BX Cam with the East Asian VLBI Network (EAVN), which is the first scientific output of the ESTEMA (EAVN Synthesis of Stellar Maser Animations) project. The data reported here cover the period from May 2018 to June 2021 at 3–4 weeks intervals, except during the EAVN maintenance season (June–August). The result is the astrometric animation, over three stellar pulsation cycles. The absolute positions, proper motions, and annual parallaxes of masers are determined using the dual-beam astrometry with VERA (Japanese VLBI Exploration of Radio Astrometry), which has joined the ESTEMA observations as a sub-array. The derived parallax is consistent with Gaia EDR3 and previous VLBI parallaxes. The stellar position with respect to the H2O maser distribution is registered by a ring of silicon-monoxide (SiO) masers using the source-frequency phase-referencing (SFPR) technique that was applied to the data taken with the multi-frequency receiving system of the sub-array KVN (Korean VLBI Network). The derived stellar position is consistent with that of Gaia EDR3 within 3 mas. The three-dimensional H2O maser kinematics indicates that the circumstellar envelope is expanding at a velocity of 13 ± 4 km/s, while there are asymmetries in both the spatial and velocity distributions of the maser features. The H2O maser animation also directly visualizes the propagation of heat waves in the circumstellar envelope of this star through rapid change in the global maser spatial distribution.

KEYWORDS masers—stars: individual (BX Cam)—stars:evolved, astrometry, kinematics, radio inter-ferrometer

Proper Motions in the Outer Halo and beyond the Milky Way

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Proper motions (PMs) from Gaia and HST have revolutionized the field of Galactic archaeology in the Milky Way (MW). However, PM studies in the Outer Halo and beyond the MW are still in their early stages with reliable measurements only being available for a small number of objects. In this presentation, I will review the status of PM measurements currently available for stellar systems beyond the MW, and describe ongoing efforts to increase their quantities and qualities. Preliminary results from some of the HSTPROMO's projects including PM measurements of Crater-Leo Group as well as the satllites galaxies of M31 will be presented. I will also discuss prospects using future data obtained with observatories like the JWST.

KEYWORDS Astrometry, Proper Motions, Local Group

FM 7
#881

Advances in VLBI Astrometry

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Very Long Baseline Inteferometry (VLBI) at radio wavelengths can yield astrometric accuracies better than +/-5 micro-arcsec, comparable to and even better than Gaia. Since radio waves do not suffer from dust extinction, this allows one to measure parallaxes and proper motions throughout the entire plane of the Galaxy. Applications include mapping the spiral structure of the entire Milky Way, parallax distances to X-ray binaries,and even extragalactic proper motions. In this talk, I will summarize recent results and describe advances in techniques, which allow wider application of VLBI astrometry in the future.

KEYWORDS astrometry, VLBI

Astrometry of exoplanets with optical interferometry

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Urbain Le Verrier, 175 years ago, was able to predict the existence and position of Neptune from the trajectory of Uranus. Could we make similar detections with exoplanets? Such an idea was demonstrated last year on Beta Pictoris b, showing that the presence and position of Beta Pictoris c could be inferred by the astrometry of Beta Pictoris b. During this talk, I will present the technique that made this possible: optical interferometry. I'll show how it's used to achieve an accuracy of a few tens of microarcseconds. I will continue by presenting the latest results from our monitoring program of young giant exoplanets. I will finish by showing the synergy between the relative astrometry of optical interferometry and the absolute astrometry of the Gaia observatory.

KEYWORDS

FM 7

#1824

VLBI astrometry in the epoch of Gaia

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Phased-referenced VLBI astrometry can yields astrometric accuracies, and trigonometric parallax measurements, with an accuracy comparable with the Gaia satellite (of order 10-50 mu-as). This capability has been used in the last two decades to measure the distance to highly obscured objects such as masers across the galactic disk or young stars embedded in two parental cloud. In this talk, I will summarized the results of a large VLBA survey called GOBELINS that measured the distance to about one hundred young stars within a few hundred parsecs of the Sun and will discuss how these results compare to Gaia's. I will emphasize the advantages of the VLBI technique over ground and space-based techniques in the study of binary stars (for instance, the possibility of resolving binaries separeted by a mere few mas and of accurately measuring the masses of individual components in such systems). Finally, I will discuss the prospects of VLBI astrometry for the coming few decades.

KEYWORDS astrometry, VLBI, young stars

FM 7
#3425

Five Years of USNO 50% VLBA Time

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We present an overview and status update of the past five years of the United States Naval Observatory's (USNO's) 50% timeshare allocation on the Very Long Baseline Array (VLBA). Beginning in January 2017, the USNO began a 50% timeshare agreement on the VLBA primarily for maintaining, improving, and monitoring the International Celestial Reference Frame (ICRF). USNO uses the VLBA for many scientific applications including measuring the precise positions of quasars that comprise the ICRF, imaging quasars to study source structure and determining quasar peak and integrated radio flux densities. In 2018, the USNO began a research project called the Fundamental AGN Monitoring Experiment (FRAMEx) to monitor various aspects of AGNs as they relate to the Celestial Reference Frame. The initial FRAMEx investigation is a volume-complete sample of Active Galactic Nuclei (AGN) systems with simultaneous VLBA and X-ray observations. The first results from this project will also be presented.

KEYWORDS

FM 7

#2702

Comparing Images of ICRF Sources at S, X, K and Q-band

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[2]Radio Astronomy, South African Radio Astronomy Observatory, South Africa
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We have undertaken an exploratory Q-band (43 GHz) imaging-astrometry project targeting the K-band ICRF sources in three sessions each of 24 hours using the Very Long Baseline Array. The project's goal is to compare images and astrometry from Q, K, X and S-band in order to study the optimal frequency band for CRF observations. The sources were observed as close as possible temporally and typically within the same week, in order to avoid problems with source variability. We will show how source structure compares between all four bands, and the interplay between source structure, resolution, and astrometry. We hope to use the results from our campaign to determine if pursuit of a Q-band CRF is worthwhile.

KEYWORDS Astrometry, AGN

FM 7

#1097

Three years of ICRF3 source positions

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Precise astronomical reference frames are extremely important for a wide variety of applications in the broader community, including astronomical observations and navigation, to name a few. ICRF3 is the third realization of the International Celestial Reference Frame, created from the combined international efforts of nearly 40 years of VLBI radio observations of thousands of quasars. In the time since the adoption of ICRF3 in August 2018, many additional astrometric and geodetic observations have been carried out, allowing for a regular cadence of global solutions which estimate updated earth orientation parameters as well as celestial reference frame source positions. In this work, we examine shifts in the long-term observed positions as well as the combined solved radio positions of ICRF3 sources over the past three years, derived from VLBI global solutions.

KEYWORDS Astrometry, Reference Frames, ICRF, VLBI

FM 7

#879

Status of the Multi-Wavelength Reference Frames

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Since the advent of the ICRF1 in 1998 as the formal realisation of the ICRS, the successive solutions (ICRF2, ICRF3) have been produced from VLBI astrometric observations of distant compact sources in the radio domain. Originally in the S/X-band, this was recently extended with independent solutions in the K- and X/Ka-bands, allowing already to see systematic differences, probably not all linked to the change of the emission centre with the wavelength. This choice of a solution in the radio domain, was not imposed by ICRS prescriptions, but just a contingent temporary situation when only the VLBI technique was in position to reach a sub-mas astrometric accuracy for this realisation, widely outperforming the available optical astrometry. As expected this has dramatically changed in the recent years with the optical realisations achieved with the Gaia spacecraft released in 2018 and 2021. An IAU resolution in September 2021 has now recognised the availability multiple solutions and redefined the fundamental reference frame accordingly.

I will present in parallel the main properties of these solutions, together with the key issues that have emerged from their comparisons. We see now plain differences that clearly won't be resolved by more accurate solutions and give evidence of positional difference in a large fraction of the common sources, to such an extent that one must select strict procedures to ensure that these frames have compatible fundamental planes and origins.

KEYWORDS Astrometry, ICRF, Reference frames, Gaia, VLBI

FM 7
#990

Astrometry with the ELT

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In the last years, precision astrometry has shown incredible potential as a tool to investigate the formation and evolution of our Galaxy and the Local Group. The future for this kind of science appears even brighter, with several facilities that will be dedicated to its further development. In this talk I will focus on MICADO, which is the first-light imaging camera of the European Extremely Large Telescope. I will outline the capabilities of the instrument, which is designed to work either in a stand-alone mode or together with the Multi-Conjugate Adaptive Optics facility MAORY. The current status of MICADO development will be described, together with the proposed strategy to achieve the outstanding astrometric precision of 50 micro-arcsec. Finally I will highlight the primary astrometric science cases that such a revolutionary facility will enable to investigate for the first time.

KEYWORDS Astrometry, Stellar populations, Extremely Large Telescope

FM 7
#1520

The X/Ka 2022b VLBI Celestial Reference Frame

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The X/Ka-band (8.4/32 GHz) Celestial Reference Frame became one component of the ICRF-3 in 2018. In the four years since, the X/Ka data set has increased by about 60% as well as adding the much needed north-south geometry from Japan to Australia. The latest solutions show that formerly large spherical harmonics distortions are greatly reduced with the Z-dipole term reduced from 314 μas to statistical insignificance and with the quadrupole 2,0 magnetic term reduced by 40%. The median formal precisions of 48 μas in right ascension and 70 μas in declination are comparable to recent S/X solutions for the more than 500 common sources. Noting that the X/Ka frame is derived from a limited geometry of only five observing sites, we discuss the importance of using full covariance information when evaluating this frame. Finally, we discuss the prospects for future improvements including the use of correlated noise to weight the solution.

KEYWORDS Astrometry, VLBI, Ka-band, ICRF, AGN, quasar

FM 7

#2709

Current Celestial Reference Frame Status at X/S and K Bands

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The third realization of the International Celestial Reference Frame, ICRF3, was finalized in June 2018 using VLBI sessions through March 2018. It was accepted by the IAU in August 2018 and became official on Jan. 1, 2019. ICRF3 contains 4536 sources in its X/S catalog and 824 sources in its K band catalog. In the 4 years since the finalization of ICRF3, dedicated astrometric campaigns have been made to maintain, improve and expand the ICRF at X/S and K bands and now four additional years of observations are available. In the northern hemisphere, these campaigns have used the VLBA at both X/S and K bands under the USNO's VLBA time share allocation. And in the southern hemisphere, the HARTRAO-HOBART26 network has been used at K band. These sessions, as well as the IVS sessions, have added ~20% more sources to the X/S catalog and ~25% more sources to the K band catalog, along with significant reductions in the scaled formal errors. We will present the current state of the X/S and K band CRF catalogs, including the distribution of sources and observations and improvements in the scaled formal errors.

KEYWORDS ICRF3, VLBI

FM 7

#3100

Imaging and Structure Analysis of ICRF sources at X and K-band

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The third and most recent realization of the International Celestial Reference Frame, the ICRF-3 included data up to 2018 from the original S/X frequencies as well as observations at K-band (24 GHz) and at X/Ka-band (8.4/32 GHz), extending the ICRF up from 8 GHz for the first time. The K-band Celestial Reference Frame (CRF) has matured greatly in recent years, allowing K-band to achieve source position precision comparable to the S/X CRF.

The use of K-band is motivated by the fact that the sources are generally intrinsically more compact at higher frequencies, as well as by the factor of three improvement in interferometer resolution relative to S/X frequencies. Astrometric-imaging observations using the VLBA have been used to create sensitive, high resolution, multi-epoch images of our sources at K-band from which we derive quantitative estimates of source strength, size, compactness, and the temporal stability of these quantities. Recent multi-epoch, quasi-simultaneous S/X and K-band astrometric-imaging observations using the VLBA, allow us to directly compare the source structure at S/X and K-band and allow us to characterize astrophysical systematics in the CRF.

KEYWORDS astronomical coordinate systems, radio astrometry, Radio source catalogs, very long baseline interferometry, extragalactic radio sources, radio continuum emission, high angular resolution

FM 7
#3426

New explanation of the observed large positional offsets between radio and optical coordinates of the extragalactic objects

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Some authors have reported a significant offset (up to several hundred milliarcsec) between the positions of reference astrometric objects (AGNs and quasars) measured in optical (Gaia) and radio wavelength (VLBI). Different physical reasons were suggested to explain this effect. Here we show that these observed radio-optical offsets may be variable. While the optical and radio positions of a quasar coincide at one epoch, they may show a 100-mas offset at another epoch. Analysis of VLBI observations revealed that some of the reference sources display a dramatic shift in their positions on time scale from 3 to 25 years in radio domain. Moreover, this shift is consistent to the apparent separation between the core and jet, therefore, it could be presented as a result of the brightness variability of one of these components. Overall, this unusually large positional instability in the quasar's radio coordinates may be purely responsible for the observed discrepancies in the radio-optical positions at the selected epochs.

KEYWORDS

FM 7

#2059

Ultra-precise Astrometry with the SKA

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We are at the cusp of a generational shift in the power of radio interferometers, with both the SKA and ngVLA planning for exciting new and powerful instruments. These will be used in conjunction with other radio telescopes to provide VLBI with an order of magnitude greater sensitivity. Furthermore, the new frequencies that will be covered will allow enhanced VLBI observations of sources that can only be observed at high frequencies (e.g. various maser lines) or low frequencies (e.g. pulsars slightly misaligned with our line of sight).

We have been exploring the implications of these new instruments, as sensitivity alone will not improve over the current astrometric limits - these being systematic. Traditional techniques for differential phase referencing will not be able to significantly overcome the systematic limits, nor extend the current moderate range of frequencies where such methods can be expected to work.

Fortunately, new methods such as Source/Frequency Phase Referencing and/or MultiView Astrometry both reduce the systematic limits and extend the range of operating frequencies. Preliminary steps have been taken to confirm that these new methods will deliver on their promise; future applications that make full use of these capabilities will allow for major improvements in the astrophysical understanding of our Universe.

KEYWORDS SKA, Astrometry, Next-generation instruments, Next-generation methods, VLBI

The Hidden Regions – Future space astrometry in the Near InfraRed

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Our Galaxy contains many different types of stars and planets, interstellar gas and dust, and dark matter. These components are widely distributed in age, reflecting their formation history, and in space, reflecting their birth place and subsequent motion.Objects in the Galaxy move in a variety of orbits that are determined by the gravitational force, and have complex distributions of different stellar types, reflecting star formation and gas-accretion history. Understanding all these aspects in one coherent picture is being partially achieved by Gaia, which surveys around 1% of the Galaxy and is still ongoing today. However muchmore could be done by using Near InfraRed light to peer through the dust and gas to reveal the hidden regions of the Galaxy.

A new all-sky Near InfraRed astrometric mission will expand and improve on the science of Gaia using basic astrometry. Near InfraRed astrometry is crucial for penetrating obscured regions and for observing intrinsically red objects. The new mission is aimed at surveying around 10-12 billion stars of the Galaxy, revealing important new regions obscured by interstellar gas and dust while also improving on the accuracy of the previous results from Gaia. There is no single science case to point to, instead the mission will explore the Galaxy, particularly the hidden regions, to reveal nature's true complexity and beauty in action.

In 2019 ESA announced the next planning cycle for their long term Science Programme, called Voyage 2050. The program called for White Papers outlining new ideas for future space mission themes. In June 2021 Voyage 2050 finally set sail, with ESA having chosen its future science mission themes. Our proposal on All-Sky Visible and Near Infrared Space Astrometry has been selected as one of two possible themes for a future Large category mission for ESA or as a Medium class mission with international partners. This talk will give an update on the science goals, the mission design and its current status.

KEYWORDS Astrometry, Galactic Astronomy, Dynamics, Parallaxes, Proper Motions, Survey Mission

FM 7
#1964

Spectroastrometry with Photonic Lanterns

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New frontiers of astronomical science push the imaging capabilities of modern adaptive optics (AO)-equipped telescopes. Examples included studies of planet formation through high-contrast imaging studies of exoplanets and circumstellar disks, and studies of accretion and outflows in circumstellar environments. However, precision measurement at the diffraction limit is made challenging by time-varying residual aberrations in AO-corrected wavefronts. Photonic lanterns are a novel technology with the potential to enable new capabilities in precision measurement at the diffraction limit through the exploitation of their novel spatial filtering and coherence properties. We present the potential sensitivity of photonic-lantern spectrometers for determining two-dimensional spectroastrometric signals for emission-line sources as a function of AO residual wavefront error.

KEYWORDS spectro-astrometry, photonic lanterns, high-contrast imaging

FM 7
#2280

StarHorse parameters for spectroscopic surveys with Gaia EDR3: ages for sub-giants and chemical substructures in the solar vicinity

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The ESA's astrometric flagship mission Gaia has added an invaluable wealth of astrometric and photometric data for more than a billion stars in our Galaxy (Gaia Collaboration et al. 2018). The synergy between Gaia's early third data release, EDR3, and the large set of spectroscopic surveys gives us comprehensive information about individual stars. To complement these data sets, we deliver new catalogues of distance, extinction, masses, and additional parameters produced with the Bayesian isochrone-fitting code StarHorse (Santiago et al., 2016, Queiroz et al., 2018). As input, we collect spectral information from surveys such as GALAH+ DR3, LAMOST DR7 LRS and MRS, APOGEE DR17, RAVE DR6, SDSS DR12 and Gaia-ESO DR3 and combine it with Gaia EDR3 parallaxes and photometry. With all this information, we release a sample of 5 million unique stars with StarHorse results extending the precision of distances and extinctions where only Gaia parallaxes would be uncertain. We also make public ages for the sub-giant regime, approximately 960k stars, with mean age uncertainties around 20%. The resulting catalogues are essential to model the Milky Way's chemo-dynamical history and work as optimal training sets in machine learning techniques to expand these results beyond the data where spectra are available. To further validate and analyse these samples, we show age-dependent chemical relations (chemical clocks) and apply the dimensionality reduction technique t-SNE with the clustering method HDBSCAN to find groups with similar ages and compositions. We show that in all different surveys, we can recover the genuine chemical thick disk, which exhibits a low age dispersion indicating its rapid formation and in agreement with recent works using precise ages measured by asteroseismology (Miglio et al. 2021).

KEYWORDS stars: statistics, stars:distances, stars:fundamental parameters, Galaxy: disk, Galaxy: stellar content

FM 7

#3430

When Gaia meets LAMOST

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As a spectroscopic survey with more than 10 million observed stars, LAMOST provides a perfect dataset with stellar atmospheric parameters and precise radial velocities covering almost all types of stars. This allows for an abundant of studies on the Milky Way and searching rare and valuable stellar objects, which helps to better understand stellar physics and stellar evolution. With Gaia, which provides accurate parallax and proper motions as well as multi-band photometry, LAMOST data has been significantly enhanced and most of the stars are now ready with 6-D phase space coordinates as well as chemical abundances. In this talk, I will briefly review how Gaia+LAMOST achieved in the Milky Way and stellar physics studies. I will show you the detection of the far end of the Sgr stream, frontiering the edge of the Galactic disk, mapping the asymmetric motion in a large range of galactocentric radii in the Galactic outer disk, revealing the early formation history of the Galactic thick disk etc. I will also show how the Gaia astrometry, combined with LAMOST stellar parameters, helps to make improvement in case-study and population properties of binary stars.

KEYWORDS

FM 7
#505

Precision Galactic Archaeology: Revealing the Milky Way's Engines through the Statistical Alignment of Stars

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The unprecedented precise astrometry of Gaia eDR3 has propelled the study of the Milky Way to enter a phase akin to where cosmology was two decades ago. Classically, the study of the Milky Way focuses mainly on blockbuster events, such as Galactic streams and dynamical resonances. However, these blockbuster events are most likely just showing us the tip of the iceberg. Much of the subgrid physics of the Milky Way only manifests itself through the subtle alignments of stars. Fortunately, such statistical patterns of the Milky Way are readily perceivable with the massive astrometry surveying of stars that densely cover the Milky Way. In this talk, I will discuss how we can extract subtle phase space and chemical fluctuations in the Milky Way and how these fluctuations present enormous new opportunities to reveal the invisible engines that drive the formation of stars and galaxy evolution.

KEYWORDS Astrometry, Gaia, Star Formation, Statistics

e-Posters

FM 7

#3088

Alignment and distortions of the Gaia celestial reference frame and the three components of ICRF3

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The International Celestial Reference Frame, version 3, provides the best available realization of an inertial, non-rotating, system of celestial coordinates. This presentation describes in-depth analysis of the three components of ICRF3 (observed in the S/X, K, and X/Ka wave bands) relative to the optical counterparts in the Gaia EDR3 catalog. The three vector fields of position differences Gaia - ICRF3 are fitted with uniform sets of 48 vector spherical harmonics up to degree 4. Significant differences are found between these decompositions. The smallest Euler rotation angles, represented by the magnetic harmonic terms of first degree, are found for the S/X catalog as expected, where the largest estimate has a S/N = 1.3. The only statistically significant harmonic with a S/N > 3 is EVSH_020, which is a zonal pattern with vectors in both hemispheres directed toward the equator. The fit for the K catalog also includes only one term with a S/N > 3, which is EVSH_211. The X/Ka band catalog, on the other hand, has a much greater and radically different distortion pattern dominated by several low-degree harmonics, the most significant one with a S/N > 9 being the zonal EVSH_010, which is a streaming field from the south pole to the north pole. This part of ICRF3 cannot be used as intended without appropriate corrections. The overall rates of significant radio-optical position offsets also widely differ between the components. Above the 3 sigma level of confidence, the rates are 25%, 19%, and 35% for the S/X, K, and X/Ka bands, respectively. The detected distortions are likely to originate in the ICRF3 parts rather than in the optical Gaia CRF.

KEYWORDS astrometry, ICRF3, Gaia

FM 7

#2773

GRAVITY Astrometry of the Young Triple Star TWA5

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The VLTI instrument GRAVITY was designed to measure not only visibilities, but also astrometry with micro-arcsecond precision. This opens new possibilities for orbit and mass determinations of young multiple stars.

One special application are triple systems, where we can determine the separation, position angle, and flux ratio of the inner binary from its visibilities, while simultaneously measuring its position relative to the third component. This way, we can determine the individual orbits and masses of the binary components, not just the sum of their masses.

The method was used for the first time in our observations of the young triple star TWA5.

The data reduction is still experimental since the astrometric mode is only partially supported by the ESO pipeline. We describe our approach to reduce the data and present first results of this project.

KEYWORDS pre-main-sequence stars, binaries, interferometers, astrometry

FM 7

#2136

Standards of Fundamental Astronomy

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The Division A functional working group, Standards of Fundamental Astronomy (SOFA), continues to establish an accessible and authoritative set of algorithms and procedures that implement standard models (including IAU Standard models) used in fundamental astronomy with regular updates to ensure the software remains relevant. This poster gives an overview of the service SOFA provides and emphasizes the current software included in the collection SOFA makes available in fourteen areas including Astrometry, Earth Rotation and Precession-Nutation. These are topics of interest for Astrometry in the 21st century.

KEYWORDS Authoritative, Algorithms, Proceedures, Standard Models, Fundamental Astronomy, Transformations, Time

FM 7
#1783

NASA Planetary Data System's Small Bodies Node Distribution of the Minor Planet Center Database and the SBN/MPC Annex

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The Minor Planet Center (MPC) based at Harvard University's Center for Astrophysics is the IAU-sanctioned clearing house of small-body positional data and is responsible for classification of these asteroids and cometary objects by type. Currently, the observed data, orbital elements, and MPC-generated products have been made publically available through a variety of web-posted files and tools and through a live exported database that is populated as part of each submission's end-processing. In order to speed processing to increase capacity for future planned surveys, the MPC is switching to a relational database processing system, and will export their live database for public consumption.

The MPC's overseeing organization, the NASA Planetary Data System's Small Bodies Node, using its hardware resources in support of the MPC, will be responsible for the distribution of the live copies of the MPC-generated database to interested users. SBN already exports a Beta-release version, and provides products to report the status, health, and growth of the database to its user base through the SBN's MPC Annex website. We will provide a description of the available MPC database Beta-release, as well as the plans for the imminent future developments, and the current and future features within the SBN's MPC Annex.

KEYWORDS Small Bodies, comets, asteriods

FM 7

#1884

Investigation of stars observed in the observation area of JASMINE

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The infrared astrometric satellite JASMINE will measure the position and motion of stars in the galactic bulge with unprecedented accuracy. We plan to use a telescope with a primary mirror diameter of approximately 40 cm. The detector to be used is the InGaAs near-infrared detector, which has recently been developed mainly at the National Astronomical Observatory of Japan. The number of observed objects was quantitatively estimated using existing catalogs such as Gaia, VVV, 2MASS, and Galactic Nucleus Survey for the purpose of reconfirming what kind of stars and how many stars are observed by JAMSINE. We are also quantifying how many Mira-type variable stars will be observed by magnitude and period.

First, the conversion formula was clarified from the magnitudes such as I and J of the stars in the catalog to the magnitude Hw in the observation band in JASMINE. Then, by comparing with the data of GaiaEDR3, we investigated the current situation such as how far the stars in the observation area of JASMINE can be measured by Gaia. We also investigated the color distribution of stars observed by JASMINE from catalogs such as 2MASS, SIRIUS, and VVV. Observations by APOGEE showed the presence of NSD (Schonrich et al. 2015). We also examined whether such stars would be observed in JASMINE, and confirmed that NSD objects in the galactic center were certainly observed in JASMINE. As described above, we will examine the situation of stars observed in JASMINE from observation data such as 2MASS, SIRIUS, VVV, or Gaia and APOGEE.

KEYWORDS astrometry, infraled, galaxy, nuclear bulge, JASMINE

FM 7

#1171

Gaia EDR3's Reanalysis of Galactic Open Star Cluster NGC752

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We present the results of deep study of the open star cluster NGC752 based on our analysis of the Gaia EDR3 data (A.G.A. Brown, et al., A&A, vol. 649, A1,2021). An angular radius of NGC752, its distance from the Sun and the age are estimated as ~ 0.5°, ~ 450 pc and 1.3–1.5 Gyr (M.A. Agüeros, et al., ApJ, vol. 862, 33 (2018), respectively, based on its known members (M. Agarwal, et al., MNRAS, vol. 502, 2582, 2021; S. Bhattacharya, et al., MNRAS, vol. 505, 1607, 2021). The ASteCA package (G.I. Perren, R.A. Vázquez, and A.E. Piatti, A&A, vol. 576, A6, 2015) was used for automated analysis of the main parameters of the cluster for statistical verification of the physical cluster true allocation from random super densities of field stars. The set of functions included in the code applies astrometric and photometric data to obtain objective precise values for the given coordinates of the cluster center, radius, luminosity function and integral value of the color index, accurate estimations of metallicity, age, redness and distance to the cluster by the isochron selection method based on the generation of synthetic cluster on the base of theoretical isochrones and the selection of the maximum match using a genetic algorithm. 44 new members of the cluster were reliably detected with a membership probability in the range from 0.81 to 1 (302 stars in total), which supplement the number of known member stars (258) within NGC 752 (M. Agarwal, et al., MNRAS, vol. 502, 2582, 2021; S. Bhattacharya, et al., MNRAS, vol. 505, 1607, 2021). We considered the stellar density profile from the center, the diagram of proper motions of the stars of the cluster NGC752 with mean values $\mu_\alpha \cos\delta$ = 9.790 mas / yr, μ_δ= -11.784 mas / yr; the comparative histogram of parallaxes of the identified probable cluster members and the field stars and the initial mass function (IMF) with cluster z(metallicity)= 0.00797± 0.00087, log(age)=9.352±0.030 , distance modulus $(m\text{-}M)_0$=8.258±0.023.

KEYWORDS Open Star Cluster, Gaia EDR3, astrometry, membership, individual stars

FM 7
#1318

Ground based meteor radar of Kazan Federal University

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Currently, sources of meteor particles that fall into the upper atmosphere when the Earth moves in its orbit are being actively investigated. For this, the radiometric method is very actively used. This method is based on the radiolacation of meteor trails that appear as a result of the ionization of air in the mesosphere – the lower thermosphere (75-110 km) during the combustion of meteors. Radiometric observations of meteor showers are actively conducted at Kazan Federal University. Regular observations began in 1978, and the first data measuring the heights of meteor combustion began in 1985. In 2015, a Skiymet-type meteor radar of joint Canadian and Australian production was installed. The KFU meteor radar consists of a phase interferometer (five two-element crossed receiving antennas of the Yagi-Udo type) with bases of wavelengths 2 and 2.5, a transmitting antenna (crossed three-element antennas), as well as a transmitter with a power of 15 kW per pulse (average power of about 1 kW) with a carrier frequency of 29.75 MHz and a pulse repetition frequency of 1594 Hz.

The meteor radar of Kazan Federal University (56N, 49E) is constantly being upgraded. The results of modernization are presented: a significant increase in the number of meteors and the accuracy of the estimation of angular coordinates and heights.

KEYWORDS meteor radar, meteor shower, meteor particle, meteor astrometry

FM 7
#899

ALMA Astrometry of the Nuclear Star Cluster

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Atacama Large Millimeter/Submillimeter Array (ALMA) is promising to be a powerful tool for precision astrometry of the area around Sagittarius A* (Sgr A*) because of it's high angular resolution, high sensitivity, and wide field of view. We have observed t the area around Sgr A* including the Nuclear Star Cluster at 230 GHz with ALMA in October 2017. The angular resolution is ~0.03". We determined the positions relative to Sgr A* of ~70 compact objects in the area with the accuracy of ~0.001". We also analyzed the similar ALMA archival data obtained in June 2019. We determined the relative positions in these objects and derived the proper motions relative to Sgr A* by comparing these positions. The positions and proper motions are almost consistent with those by previous infrared observations. The derived proper motions are roughly described with both clockwise and counterclockwise rotations around Sgr A*. The rotation velocities are reproduced by Kepler orbits bounded around Sgr A* without a few exceptions. Moreover, they include co-moving clusters for example IRS13E and IRS13N. Therefore, they demonstrate that ALMA is a powerful tool for precision astrometry of the area.

KEYWORDS astrometry, proper motions, Galaxy: center, Galaxy: kinematics and dynamics, stars: massive

FM 7
#428

On the long-term ICRF stability

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The International Celestial Reference Frame (ICRF) based on the VLBI-derived positions of extragalactic radio sources was adopted by the International Astronomical Union (IAU) in 1998.
Later, in 2009 and 2020, two extended ICRF versions, ICRF2 and ICRF3, were released, respectively.
The latter is adopted by the IAU as the current implementation of the ICRF.
Due to large distance to ICRF objects, mainly active Galactic nuclei (AGN), the ICRF is more systematically stable than the replaced FK5 optical frame.
However, the ICRF3 system is also evolving with time primarily due to physical processes in AGN.
Several studies were recently devoted to investigation of this problem.
In this work, new strategies will be discussed to assess the long-term stability of the ICRF.

KEYWORDS Reference frames, ICRF, Stability

Comparing the new MOG theory with dark matter approach in extragalactic context

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Distribution of dark matter in Universe is a long-standing problem of astrophysics and cosmology. Flat rotation curves of galaxies belong to one of the most significant observations supporting dark matter theory. However, there are other alternative approaches to gravity. In this work, we confront the rotation curves of observed galaxies with predictions of dark matter approach and a new modified gravitational (MOG) theory We take into account MOG theory based on observational results of McGaugh et al. (2016). The generalization of the new MOG theory allows to determine the rotation curve of galaxies from an arbitrary given gravitational potential. We fit the latest observational values of the rotational speed of the Milky Way galaxy with minimal deviations. Moreover, we examine the theory on a larger sample, we apply the method on acceleration of galaxies from the SPARC catalogue. We compare the results with the dark matter approach as well.

McGaugh et al., 2016. PRL, 117(20), p.201101.

KEYWORDS galaxies, gravity, dark matter

e-Talks

FM 7

#380

Astrometry From Hipparcos to Gaia: Parallax Discrepancy

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In spite of the fact that Gaia astrometric space mission promises a dramatic improvement in the available data of the parallax measurements, we still find discrepancy in the measurements between Gaia and Hipparcos catalogues that cannot be ignored. We present the results of comparing parallax measurements given by the catalogues of Hipparcos 2, Gaia DR2, and Gaia EDR3.

We focused on stars with parallax discrepancy between Hip 2 and Gaia DR2 greater than 5 mas, as clear cases which need to be solved using either new measurements or another computational technique. Among a sample of around 1700 BMSSS, with known orbits from the sixth.., we found that there are 55 systems have parallax discrepancies between Gaia DR2 and Hip 2. 10 of these these systems have no parallax measurements in Gaia EDR3.

The study shows that there is a clear problem in Gaia DR2 parallax measurements for BMSSs. And in spite of the fact that Gaia ERD3 improved the measurements, there are still some systems with a clear problems in their parallaxes, with favoring to Hip 2.

We present a solution for one of these cases as an example. It is the stellar system Hip 45858. Where we found that Hip 2 parallax measurement is the closest to the dynamical one calculated in this work, which is the best way for identifying parallaxes of BMSSs.

Our main recommendation is that Gaia parallax measurements of BMSSs need special attention in the data reduction process.

KEYWORDS Stars: binaries, stars: binaries: visual, Stars: parallaxes: Astrometry, Stars: multiple

FM 7

#1458

Luminosity function of white dwarfs and discovery of new white dwarfs by means of Gaia EDR3 data

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The discovery of new White Dwarfs (WDs) is extremely important for understanding the kinematics and dynamics of the local stellar population. They are evolutionary signatures of the Milky Way, as most of stars pass through this evolutionary stage. Gaia's astrometric accuracy allows more detailed studies of WDs and many other stars. We have constructed the luminosity function for McCook & Sion White Dwarf catalogue objects based on distances provided by Gaia EDR3. We have revealed among 640 First Byurakan Survey UV-excess stars objects with proper motions (PM) >10 mas/yr. Adopting 50 km/s upper limit for tangential velocities, we calculated maximum distances and absolute magnitudes and estimated luminosity types for these objects, revealing 185 probable ($M > 8$), 69 possible WDs ($6 < M < 8$) and 42 candidate subdwarfs/WDs. The Digitized First Byurakan Survey (DFBS) is more efficient for discovery of new WDs by spectral energy distribution. Using Gaia data for accurate parallaxes and distances in combination with DFBS low-dispersion spectra and additional multiwavelength data, during the pilot survey we have revealed thousands of new WDs and candidate subdwarf/WDs. Many of them are subject for studies on binarity and variability. Gaia DR3 will provide huge amount of data to confirm these WDs and reveal many more such objects.

KEYWORDS White Dwarfs, Astrometry, Gaia, Luminosity Function, Absolute Magnitudes, Distances, Proper Motions

FM 7
#1463

The NAROO program

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The NAROO program has been created at Paris Observatory, Meudon, as a unique centre dedicated to the digitization and the analysis of old astro-photographic plates for scientific purposes, only.

The NAROO digitizer consists of a granite-based Newport-Microcontrol open frame air-bearing XY positioning table, a scientific sCMOS camera, and a telecentric optical system. The machine is placed in an overpressure, air-conditioned, ISO-5 clean room to maintain its positioning stability better than 15 nm, and its accuracy better than 65 nm.

The renewed interest about photographic plates concerns the expansion of the database of transient objects evolving in time, since 1) digitization now makes it possible to measure images with a high level of accuracy and to identify all the available objects, 2) the arrival of the Gaia reference catalogs allows to realize reductions for past observations with today accuracy. The information extracted from such materials can be of an astrometric, photometric, and spectroscopic nature, when not purely imaging, with consequences in planetology, near-Earth asteroid risk assessment, astrophysical phenomena, and general relativity, to mention but a few. Since we invite researchers to use our facilities and digitize their collection (free of charge), we detail current and upcoming uses for the community: precoveries, small bodies, planetary satellites, Sun, Be stars, SMC and LMC observations for example.

KEYWORDS Astrometry, Digitization, Photographic plates, Dynamics, Ephemerides, Solar System

FM 7
#681

Overview and recent progress of JASMINE: near-infrared space astrometry mission

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JASMINE is a satellite mission to perform infrared astrometric observations in the direction of the Galactic nuclear bulge. The telescope has a circular primary mirror of about 40 cm diameter. JASMINE uses the infrared Hw-band, whose wavelength extends from 1.1 micron to 1.6 micron (TBD). JASMINE will determine positions and parallaxes accurate to between 25 μas and 125 μas, depending mainly on the star magnitude. The magnitude range of the stars is planned to be between 9.5 and 14.5 magnitude. The precision of the proper motions is expected to be between 25 μas per year and 125 μas per year. The number of stars to be downloaded to the ground is expected to be about 10,000 with the magnitudes mentioned above with high frequency. More than 100,000 fainter stars will be observed, and their data sent to the ground, with a lower frequency. This mission is unique in that the same astronomical object can be observed frequently, and observation will be performed in the near-infrared band, in which the effect of absorption by dust is weak.

JASMINE ("Small-JASMINE mission") was selected by ISAS/JAXA (Institute of Space and Astronautical Science/the Japan Aerospace Exploration Agency) in May 2019 for the JAXA Competitive Middle-Class Science Missions No.3. At the present, according to the progress schedule in the Space Basic Plan determined by Japanese government in December 2021, the launch of JASMINE is scheduled for 2028. After nominal 3 years of operation, the final catalog will be released in around 2033. We are promoting the JASMINE mission with the aim of gradually improving the development stage at JAXA.

This mission will help to achieve revolutionary breakthroughs in astronomy and basic physics, including the formation history of the Galactic nuclear bulge (Galactic Center Archeology) and the supermassive black hole at the Galactic Center etc. Although the Galactic center region covers only a small part of the sky, in terms of understanding our Galaxy's structure, and its formation and evolution, it is particularly important region because stars of various ages have different spatial distributions and motions according to their ages in this region. It's like having different strata in geology. I will talk about the brief overview and recent progress of the JASMINE mission.

KEYWORDS space astrometry, infrared observation, Galactic nuclear bulge, Galactic center archeology

FM 8

Planetary Astronomy via Telescopic and Microscopic Approaches

Invited & Contributed Talks

FM 8

#757

Scientific discoveries of the Hayabusa2 mission, sample return from C-type asteroid Ryugu

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The Hayabusa2 spacecraft visited near-Earth C-type asteroid Ryugu, conducted intensive observations using optical and thermal cameras, NIR spectrometer, and LIDAR, landed a lander and rovers for in-situ measurements, performed a crater-forming experiment using a carry-on impactor SCI and deployable camera, and collected surface and subsurface particles from two separate locations. In December 2020, Hayabusa2 successfully delivered Ryugu samples to Earth, and initial analysis has been performed.

The major scientific finding to be presented are as follows: Analysis of returned particles shows that Ryugu consists of CI chondrite-like primitive material severely altered by aqueous processing in a fluid with a temperature of ~310 K generated by the decay heat of 26Al in the interior of an ~100-km sized icy parent body at 5-6 million years after the formation of the Solar System. The presence of CO2 in fluid inclusions in a large iron sulfide crystal, the NIR absorption of NH in ammonium salts or organic nitrogen compounds, and the very low content of chondrules and calcium aluminum-rich inclusions (CAIs) suggest that the parent body of Ryugu may have originated outside the snow lines of CO2 and NH3 (outside Jupiter's orbit). Based on the orbital analysis of Ryugu and comparison of the reflection spectra, its parent body is considered to be one of the collisional families in the inner asteroid belt. Therefore, it is necessary to verify whether the scattering of giant planets could bring planetesimals beyond Jupiter to such an inner region of the asteroid belt. In any case, it is a great discovery that the parent body of CI chondrites are collisional families in the inner asteroid belt.

Large surface boulders and the low bulk density indicate that Ryugu was formed by the catastrophic disruption of its parent body. The large artificial crater excavated by SCI indicates very low internal cohesion of Ryugu’s surface material and a very young resurfacing age (<10 Ma). The young surface age suggests that the spinning-top shape of Ryugu may have been formed through surface landslides in the past rapid rotation induced by the YORP thermal effect.

The scientific results of the Hayabusa2 mission will link asteroid observations, meteorite analysis, and laboratory experiments to future exploration of the Solar System.

KEYWORDS Exploration, Carbonaceous chondrites, Planetesimals, Aqueous alteration, Impact crater, Sample analysis, Snow line

OSIRIS-REx – Status of NASA's Near-Earth Asteroid Sample Return Mission

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The OSIRIS-REx mission was selected in 2011. The spacecraft launched in September 2016 and began its journey to Bennu, a carbon-rich, near-Earth asteroid. The spacecraft rendezvoused with Bennu in 2018 and successfully obtained a sample in October 2020. The spacecraft embarked on its return voyage to Earth on May 10, 2021. On Sept. 24, 2023, the spacecraft will jettison the sample capsule and send it onto a trajectory to touch down in the Utah desert. Sample analysis will continue until 2025. These samples will be the first for a U.S. mission and may hold clues to the origin of the solar system and the organic molecules that may have seeded life on Earth.

The University of Arizona leads the mission for NASA and will provide sample analysis laboratories for the returned samples. NASA's Goddard Space Flight Center provides overall mission management. Lockheed Martin Space Systems built the spacecraft. United Launch Alliance built the mission's Atlas V launch vehicle. The mission is in an exciting phase right now as the OSIRIS-REx spacecraft continues its return journey to Earth.

KEYWORDS

FM 8

#2882

Overview of Space Weathering on Asteroid (101955) Bennu

Beth Ellen Clark[1], Antara Sen[2], Xiao-Duan Zou[3], Daniella DellaGiustina[4], Seiji Sugita[5], N Sakatani[6], Michelle Thompson[7], David Trang[8], Eri Tatsumi[9], Maria Antonietta Barucci[10], Michael Barker[11], Humberto Campins[12], T Morota[13], Cateline Lantz[14], Amanda Hendrix[3], Faith Vilas[3], Lindsay Keller[15], Vicky Hamilton[16], Kohei Kitazato[17], Sho Sasaki[18], Moe Matsuoka[19], Tomoki Nakamura[20], Alice Praet[10], Salvatore Ferrone[10], Takahiro Hiroi[21], Hannah Kaplan[22]

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This presentation summarizes the evidence for the optical effects of space weathering, as well as the properties of the surface that control optical changes, on asteroid (101955) Bennu as was observed by NASA's OSIRIS-REx mission. First, we set the stage for the observations of Bennu by briefly reviewing what was known about space weathering of low-albedo materials from telescopic surveys and laboratory simulations prior to the OSIRIS-REx encounter. We then look at the evidence for the nature of space weathering on Bennu from spacecraft imaging and spectroscopy observations, including the visible to near-infrared and thermal infrared wavelengths, followed by other evidence such as normal albedo measurements from lidar scans. We synthesize these different lines of evidence in an effort to describe a general model of space weathering processes and resulting color effects on dark C-complex asteroids, with hypotheses that can be tested by analysing samples returned by the mission.

A working hypothesis that synthesizes findings thus far is that the optical effects due to increasing degrees of space weathering of C-complex asteroids are dependent on the level of hydration in the parent material (e.g., presence of hydroxl/water bearing phyllosilicates). On Bennu the oldest surfaces are redder and darker at visible to near-infrared wavelengths and have shallower absorption bands due to the presence of greater amounts of nanophase and/or microphase opaques. Solar wind, dehydration, or migration of fines may cause intermediate-age surfaces to appear blue in visible wavelength images. Very young craters on Bennu are redder than their surroundings in both visible wavelength imaging and near-infrared spectra as a result of their smaller particle sizes and/or fresh exposures of organics by impacts. However, Bennu is a rubble pile with a demonstrably active surface, making age relationships, which are critical for determining space weathering signals, difficult to locate and quantify. Hence, the ultimate story awaits analyses of the returned samples.

KEYWORDS Bennu, Space weathering, optical maturation, color imaging, spectroscopy

FM 8

#914

Determination of space weathering timescale and consideration of a possible event occurred on Itokawa

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Space weathering is a surface alteration process of airless bodies caused by solar wind implantation and micrometeorite bombardment. On the other hand, resurfacing counteracts the space weathering effect, exposing fresh subsurface materials. Several resurfacing processes are proposed, such as tidal encounters with planets [1].

A near-Earth asteroid (25143) Itokawa exposed fresh materials, but the resurfacing mechanism is less investigated. We noticed four orders of magnitudes discrepancies in the space weathering timescale derived by different techniques [2][3]. To eliminate the uncertainty, we first determined the space weathering timescale by focusing on the bright mottles on the boulders and estimated it to be 1000 years. This result is consistent with the He+ ion irradiation experiment [4]. Based on this result, we discuss a possible recent resurfacing process that might have rejuvenated the Itokawa's surface.

[1] Binzel et al. (2010), Nature, 463, 7279, p. 331-334.
[2] Noguchi et al. (2014), M&PS, 49, 2, p. 188-214.
[3] Koga et al. (2018), Icarus, 299, p. 386-395.
[4] Loeffler et al. (2009), JGR, 114, E03003.

KEYWORDS Solar system, Asteroid, Space weathering

FM 8

#911

Thermal radiation pressure as a possible mechanism for losing small particles on asteroids

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Recent space explorations taught us μm-sized fine-grains are missing on smaller near-Earth asteroids (NEAs) (25143) Itokawa, (162173) Ryugu, and (101955) Bennu. Meanwhile, with sub-micron scale granular structures found in meteoritic samples, thermal fatigue or micrometeoroid impact would likely supply dust debris down to sub-micron scale on regolith. If so, there must be a mechanism that preferentially removes fine-grains on smaller asteroids. Among NEAs, (3200) Phaethon, the target of JAXA's DESTINY+ mission, repeatedly showed a detectable dust tail of 1 μm radius dust particles near its perihelion. This detection indicates that fine-grains are not only being generated but also being removed by ejection, and this generation and/or ejection process gets powerful near the perihelion, while the ejection mechanism is unknown.

This work suggests a novel idea that thermal radiation pressure exerted by the regolith can play a dominant role in ejecting those fine-grains. The model predicts the pressure is stronger (1) at smaller heliocentric distances, (2) for particles of radius ~ 1 μm, almost regardless of particle's physical properties, and (3) for smaller asteroids (weaker gravity). The first two findings from this theoretical work are consistent with observational studies on Phaethon that its dust cloud is formed only near the perihelion and consists of particles with a radius of ~1 μm. In this presentation, we discuss our findings and their implications on regolith science and the DESTINY+ mission.

KEYWORDS minor planets, asteroids, asteroids: individual: 3200 Phaethon, active asteroids, interplanetary medium

FM 8

#2596

Change of the Apophis' spin state during the 2029 Earth encounter

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On April 13, 2029, Potentially Hazardous Asteroid (99942) Apophis will closely encounter the Earth. The gravitational torque during the encounter will change the Apophis' orbit from an Aten-class orbit to an Apollo-class orbit while shifting the semimajor axis from 0.92 AU to 1.1 AU. It is also expected that the spin-state of Apophis will be significantly affected by the tidal torque as the current spin angular momentum of Apophis is relatively small. However, the change of spin angular momentum cannot be determined without the correct estimate of body axis orientation just before the 2029 encounter. This requires precise measurements of the spin state of Apophis which exhibits complex tumbling motion. Using photometric data from the apparitions in 2020-2021, we could measure the spin state of Apophis as well as its shape model with great precision. By propagating this to the time of encounter, we will present the expected spin state of Apophis after the Earth flyby.

KEYWORDS Apophis, tidal torque, tumbling asteroid, close encounter

FM 8
#2926

Tangential YORP torque due to the asteroid surface roughness

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The tangential YORP effect, or TYORP, is a light pressure recoil force changing the asteroid's rotation rate via uneven thermal radiation by the small-scale structures on the asteroid surface. TYORP has been modeled numerically for individual boulders of different shapes, but not for a rough rocky or regolith surface. Still, many asteroids are known to have large portions of surface covered by regolith, and the contribution of this regolith to TYORP needs to be accounted for. Also, the rocks producing TYORP are much rougher on different scales than the idealized models typically used in simulations.

Here, we investigate TYORP produced by a rough surface, modeled by a sinusoidal wave or a Fourier series composed of sinusoidal waves. We present a theoretical model for heat conduction in a sinusoidal wave and an approximate analytic expression for TYORP created by it (Golubov & Lipatova, A&A, accepted). Also, for the first time, we present the results of numeric simulations of TYORP created by a sinusoidal wave and by a sum of sinusoidal waves.

We apply the theory to the asteroid (162173) Ryugu and find that the tangential YORP produced by its surface roughness is at least 5 times greater than its normal YORP.

KEYWORDS Asteroids, Thermophysical modeling, YORP effect, Methods: analytical, Methods: numeric

FM 8

#2037

Subsecond Photometry of Tiny Near-Earth Objects with Tomo-e Gozen

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Material transportation by asteroids is one of the leading hypotheses regarding the origin of life and water on Earth. To test this hypothesis, it is necessary to know how asteroids move in the solar system and what kind of physical properties (i.e., strength and composition) they have. Recently, explorations and sample returns of near-Earth asteroids (NEOs) have been conducted by Hayabusa, Hayabusa2, and OSIRIS-Rex mission. While in-situ observations of asteroids with diameters D > 100 m and analyses of mm-size particles have progressed, the intermediate-sized (1 < D < 100 m) objects remain to be studied. We attempt to characterize such tiny objects via ground-based observations of NEOs.

Most NEOs have their origins in the main belt and experience the rotation changes caused by Sun's radiation, the YORP effect. Since the YORP effect is stronger for smaller objects, tiny NEOs are good targets to investigate their dynamical histories and physical properties. For example, fast rotators suffer from strong centrifugal force and may experience deformation or rotational fission when their rotation periods reach critical values by YORP spin-up. Thus, it is thought that rotation periods of tiny NEOs are related to the strength of tiny bodies.

We conducted subsecond photometry of 60 tiny (D < 100 m) NEOs with Tomo-e Gozen on the Kiso 105 cm Schmidt telescope, and we successfully derived the rotation periods of 32 NEOs. We statistically confirmed that a certain number of tiny fast-rotating NEOs were missed in previous surveys. We have discovered that the distribution of the tiny NEOs in a diameter and rotation period (D-P) diagram is truncated around P = 10 s. The truncation is not explained well either by rotational fission of NEOs or the suppression of YORP by meteoroid impact. We propose that the dependence of the tangential YORP on the rotation period potentially explains the observed truncation in the D-P diagram.

KEYWORDS asteroid, near-Earth object, photometry, lightcurve, YORP

FM 8
#745

The impact process on small bodies: review of current knowledge and implications on the Solar System history

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Collisions play a crucial role in the Solar System history. Understanding this process is thus crucial to draw a robust scenario of this history. In particular, small body collisions can lead to their disruptions or to craters that are used to estimate surface strengths and ages. Impact hydrocodes have been developed, which rely on shock and fracture physics, and are confronted to laboratory experiments on centimeter-size targets. However, their use at larger scales is confronted to different issues.

The first is that the reliability of hydrocodes at large scales is not guaranteed by lack of comparisons. Fortunately, space missions including impact experiments exist, such as the JAXA Hayabusa2 and the coming NASA DART/ESA Hera missions. The second is that in the case of a disruption, hydrocodes cannot capture the entire process. Once fragmentation is over, the produced fragments can reaccumulate due to their mutual attractions, leading to a population of gravitational aggregates and not solid fragments. Small bodies of second generation at least should thus all be rubble piles, down to sizes of 100-200 meters, which is consistent with measured small body low bulk densities. The third issue is that for cratering events on low gravity bodies, shock physics codes have great difficulties to capture the final crater size. When the cohesion is small, crater formation can take several tens of minutes and the crater is still evolving after the shock phase. Therefore, another approach is needed to capture entirely the physics of the process. This has strong implication on the estimate of surface ages, as depending on the assumptions, this estimate can differ by orders of magnitude.

In recent years, huge progresses have been achieved concerning these issues, benefiting particularly from the data of space missions on small asteroids and comets. Numerical impact models could thus benefit from new knowledge in the correct environment. This led to advances that have enormous implications in the estimate of surface ages and the history of those bodies, which can be extended to other small bodies.

I will review the knowledge from the last years thanks particularly to space missions, and numerical simulations of collisions on small bodies with their implications on their formation and evolution, for the two regimes of cratering and disruption.

KEYWORDS Collisions, Asteroids, Comets, Craters, Disruptions, Rubble piles, Aggregates

FM 8

#868

Dust trails generated on the DART experiment

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NASA sent the DART (Double Asteroid Redirection Test) mission to the asteroid binary system Didymos-Dimorphos. The mission objective is to test the asteroid deflection technique called kinetic impactor.

DART will previously release the Italian "Cubesat" LICIACube (ASI); to obtain high-resolution images of the moments after the impact. The impact will produce a crater and a large amount of material ejected at high speed (hundreds of m/s), producing an ejecta cone that will quickly disperse.

We analyze an additional effect: the lofting of material at low speed because of the generation of seismic waves that propagate into the interior of Dimorphos and, even if highly damped, generate shaking at distant surface points. To analyze this effect, we divide the process into the following steps: i) generation of impact-induced seismic waves and propagation into the interior of the body; ii) arrival of these waves coming from the interior to the surface at points located far from the impact point; iii) shaking produced by the arrival of these waves on small particles located on the surface; iv) lifting of particles due to shaking and ejection at low speed (comparable to the escape velocity); v) evolution of particles under the influence of gravity and solar radiation pressure; vi) prediction of observation of this cloud of particles from the Earth.

We anticipate the following potentially observable effects: i) generation of a cloud of small particles that will produce a hazy or fuzzy appearance of Dimorphos' limb, detectable by LICIACube; ii) a brightness increases of the binary system due to enhancement on the cross section produced by the cloud of particles; iii) generation of a dust trail, similar to those observed in Activated Asteroids, which can last for several weeks after impact.

A numerical prediction of the detectability of these effects will be strongly dependent on the amount and size distribution of the ejected particles, which are largely unknown. On the other hand, in case these effects are observable, an inversion method can be applied to compute the amount of ejected material and discuss the relevance of the shaking process as well as some elastic and structural parameters of Dimorphos.

KEYWORDS asteroid, Didymos, Dimorphos, DART, impact, kinetic impactor, dust

FM 8
#1514

The potential of optical polarimetry for asteroid studies

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Historically, optical polarimetry of asteroids was one of the main techniques in study physical properties of asteroids but up to now its potential has not been sufficiently exploited. In recent years, the number of telescopes available and used for asteroid polarimetry has steadily increased. Measurements of the phase angle dependence of the linear polarization degree of asteroids of various dynamical and compositional groups in a wide range of phase angles revealed many interesting previously unknown features. Polarimetry has been proven to provide one of the best ways to determine the albedo of asteroids. This application is especially useful for near-Earth asteroids, for which even a single measurement of the degree of polarization at large phase angles can be sufficient to obtain an overall albedo estimate. Using polarimetric measurements it is possible to refine the taxonomy of asteroids and identify several types that are poorly distinguished based on spectral data. Although the interpretation of polarimetric observations of asteroids in terms of physical parameters is not straightforward, it is evident that polarimetry provides important complimentary information that cannot be obtained by any other remote sensing technique. An overview of recent advances in polarimetric observations of asteroids will be given.

KEYWORDS asteroid, polarimetry, albedo, taxonomy

FM 8

#1126

Polarimetric Study on the Hydrates Asteroids

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Hydrated asteroids have undergone various processes, particularly aqueous and thermal alterations. Thus, observational evidence for these asteroids gives us a hint for a better understanding of the aqueous and thermal evolution. For example, (101955) Bennu was found to have evidence for widespread aqueously altered minerals via the OVIRS spectrometer onboard the OSIRIS-REx spacecraft [1]. Meanwhile, multi-band observations of the Hayabusa 2 mission found that (162173) Ryugu also contains hydrated minerals, but they might have experienced a moderate thermal alteration in its parent body [2]. Like these examples, hydrated asteroids have been studied extensively via spectroscopy or multiband photometry, focusing on absorptions near 0.7 µm and 3 µm. On the other hand, it is important to notice that Ch-type asteroids that are hydrated asteroids experienced weak thermal alteration with temperature < 400 degrees Celsius. They show different polarimetric properties (especially the minimum polarization degree, Pmin) from those of the asteroids with similar albedo [3]. However, despite their polarimetric particularity, polarimetric studies on hydrated asteroids have been scarcely conducted. To deepen our understanding, we made polarimetric observations of 18 dark main-belt asteroids including Ch-type asteroids by using the 1.6-m Pirka telescope of Hokkaido University. As a result, we confirm that 1) Ch-asteroids have very small Pmin (Most of them having Pmin< -1.5 %). Further, we found that 2) polarimetric parameters (e.g., the Pmin) show a strong correlation with spectral features (e.g., absorptions near 0.7 µm and 3 µm). In this presentation, we will share our results and interpret these results in connection with mineralogy and surface structure (e.g., grain size). [1] Hamilton V. E., et al., 2019, Nature Astron., 3, 332, [2] Kitazato K., et al., 2021, Nature Astronomy, 5, 246, [3] Belskaya I. N., et al., 2017, Icarus, 284, 30

KEYWORDS Polarimetry, Hydrated asteroid

FM 8

#2565

Hydrated silicates on evolved cometary nuclei observed in the mid-infrared

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It is thought that comets are the remnants of planetesimals formed in the early solar nebula. Silicate features are often observed in cometary spectra as a 10-μm resonant feature which indicates the existence of small crystalline and amorphous silicate grains. Short-period comets that have orbited the Sun many times, however, are expected to evolve thermally and usually show weak silicate emission features. If a comet has a very weak or no silicate feature, we can observe a comet nucleus directly.

In these 20 years, we conducted mid-infrared spectroscopic observations of a dozen short-period comets with Subaru telescope. Among them, we will show mid-infrared spectra of comets P/2016 BA14 (PANSTARRS) and 2P/Encke, which are different from ordinary comets that show silicate emission features. Gas and dust production rates of comet PANSTARRS were notably low, even near the perihelion passage around 1 au from the Sun in March 2016, and it was expected that the observation obtained the thermal emission from the nucleus. The normalized emissivity spectrum of comet PANSTARRS in the mid-infrared is similar to those of phyllosilicates which are usually not observed in the comet spectra. Moreover, it is indicated that the prominent absorption-like feature peaked at 9.50 micron is associated with dehydroxylated phyllosilicates on the nucleus surface. Comet 2P/Encke is one of the evolved comets, which has one of the shortest orbital periods (3.3 years) of any known comet within our solar system. The mid-infrared spectrum of comet Encke looks blackbody-like, but weak negative features from the continuum can be seen. We will discuss the features and the dust properties of comets PANSTARRS and Encke in our presentation. It is suggested that the results indicate that one possible end state of comets may be an inactive small body covered with coarse grains of phyllosilicate minerals, not only anhydrous silicates, combined with organic materials.

KEYWORDS comets, dust, mid-infrared, hydrated silicates

FM 8

#1944

Asteroid physical characteristics from Gaia photometry

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Photometry is a key tool for estimating the physical characteristics of asteroids. An asteroid's photometric lightcurve and phase curve refer to the variation of the asteroid's disk-integrated brightness, respectively, in time and in phase angle (the Sun-asteroid-observer angle). They depend on the asteroid's shape, rotation, and surface light-scattering properties, and the geometry of illumination and observation. We present Bayesian lightcurve inversion methods for the retrieval of the asteroid's phase function, the unambiguous phase curve of a fictitious spherical asteroid with surface scattering properties equal to those of the original asteroid. A collection of such phase functions can give rise to a photometric taxonomy for asteroids. In the inverse problem, there are four classes of lightcurves that require individual error models. The photometric observations can be absolute or relative and they can be dense or sparse in comparison to the asteroid's rotation period. The observations extend over varying phase angle ranges, gradually requiring more and more sophistigated models for the phase function. For examples, first, the photometry from the ESA Gaia space telescope extends, typically, over a range of phase angles, where the photometric phase curve tends to be linear on the magnitude scale. Second, the ground-based photometry can reach small phase angles, where the asteroids show an opposition effect, a nonlinear increase of brightness on the magnitude scale towards zero phase angle. We provide error models for the four classes of lightcurves and make use of linear or linear-exponential phase functions for phase angles below 50 degrees. We then apply the inverse methods to sparse Gaia lightcurves (from Gaia Data Release 3 or GDR3 due in June 13, 2022) and dense ground-based lightcurves. This allows us to obtain absolute magnitudes and phase functions, with uncertainties, for a large number of asteroids: GDR3 comprises some 150,000 asteroids with high-precision G-band photometry.

KEYWORDS asteroid, photometry, Gaia, phase curve, light scattering, shape, rotation

FM 8

#1456

Laboratory study for the light scattering on planetary regolith with 3D printed models

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Many airless bodies, such as the Moon and asteroids, are covered by loosely bounded particles, and it is called "regolith." For the lunar surface, it is known that the grains aggregate by weak gravity, and it consists of a structure like a fairy castle. The light scattered by such a surface shows different behavior concerning its porosity, particle size, and structure. In particular, the opposition effect, the nonlinear surge of its brightness at near-zero phase angle (i.e., the angle between the Sun, object, and detector), occurred by hiding shadows or coherently scattered light. It returns crucial information about the texture of the regolith; however, the detail relation has not been studied well. To understand how regolith's fine structure affects the light scattering on the surface, we measured the reflectance of samples in varying angular elements (e.g., phase angle, incidence angle, and emission angle). The examination samples are black resin regolith models similar to the fairy castle structure, printed by a 3D printer.

In this conference, we introduce a laboratory study for light scattering with 3D printed regolith models and show the initial results. We also suggest how this experiment contributes to future lunar exploration to observe the 3D micro-texture of the lunar regolith.

KEYWORDS scattering, regoliths, porosity, surfaces, photometry, 3D printer

FM 8
#1313

Next Generation Ground-Based Planetary Radar Science at NRAO

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Advances in astronomical radar technology are paving the way for the next generation ground-based planetary radar capabilities at the National Radio Astronomy Observatory (NRAO). These advances are opening new avenues and renewed investment and interest from the industry and scientific community overarching planetary science and planetary defense.

This talk will provide an outlook of NRAO ground-based planetary radar science goals that have the potential to substantially expand our capabilities to advance knowledge in our Solar System. Next generation planetary radar capabilities using NRAO facilities are seeking to enhance detection and imaging of solid bodies in the Solar System, including small bodies (near-Earth asteroids, main-belt asteroids, comets, extrasolar interlopers), our Moon, the terrestrial planets (with exception of Venus), moons orbiting other planets, and potentially planetary debris. These science goals would be achieved through bi-static observations with the synergy of a planned high-power transmit system on the fully steerable, 100-meter Green Bank Telescope with NRAO's existing and future receive-array capabilities, such as the Very Long Baseline Array (VLBA) and the Next Generation Very Large Array (ngVLA), for increased science return.

This talk will also seek input from the community in expanding science goals in view of a new observation program to be developed at NRAO as the new radar capabilities become available over the next decade.

KEYWORDS radar, planetary, asteroids, observations, receive-array

FM 8

#1274

The search for Planet Nine using the Subaru Telescope

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Planet Nine has been primarily proposed to explain the observed structure of the Kuiper belt objects with semi-major axes beyond 200 AU. Other lines of evidence, such as the detachment of the perihelia of outer solar system objects from Neptune, and the highly inclined orbits of some of the long period objects also point towards this hypothesis. In this talk, I will report on our multi-year observational program to search for Planet Nine with the Hyper Suprime-Cam instrument on the 8 meter Subaru telescope. We were allocated a total of 21 nights of observational time out of which we lost 40 percent due to bad weather. We were able to image over 200 sq degrees of data on multiple consecutive nights. The area covers the sky region near the apocenters of the proposed path of Planet Nine. The data was reduced with the state-of-the-art Rubin science pipelines and difference imaged in order to find moving objects. These objects were then linked to find candidates which match the orbits of Planet nine, and then finally visually inspected. We characterize the effectiveness of our detections by injecting simulated Planet nine candidates in raw imaging data, and run those through our end to end pipeline. Our pipeline is able to recover more than 90 percent of detectable simulated candidates out to a limiting magnitude of the survey (median limiting magnitude > 24). I will describe the challenges involved with the data reduction, management of a bleeding edge software pipeline over computing clusters separated over multiple continents and having to deal with a large number of false positive detections in difference images. I will report on the discovery of trans Neptunian objects from our data set and showcase some of the best candidates for Planet Nine we found in the data. Finally, I will summarize the current best constraints on the existence of Planet Nine.

KEYWORDS Outer Solar system, Planet Nine, Trans-Neptunian objects, Subaru telescope, Hyper Suprime-cam, Difference imaging

FM 8

#1370

Previously Undiscovered Exoplanets Detected with Deep Learning in the Data Collected by the Kepler Space Telescope2

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Using deep learning with the Adam optimization algorithm in this research, I detected 11 previously undiscovered exoplanets in the Kepler data. Although some of the exoplanet transit signals were evident, others were not as strong and need further evaluation. By using my own code, open source libraries, and deep learning packages such as TensorFlow and implementing the Adam algorithm as an optimizer, I developed a Python program for exoplanet detection. The program first normalizes the transit light curves, trains the deep learning model using the Adam optimizer, folds the transit light curves to intensify the transit signals, then uses the model to search for exoplanet transits in the Kepler light curves. Among the newly detected exoplanets, 9 of them are ultra-short period (USP) exoplanets with orbital periods shorter than a day, and the 2 others are short period exoplanets with periods between 1 to 10 days. Because the Kepler mission lasted for nine years and observed each star for a selected period of time, there are much more Kepler Objects of Interest (KOI) with shorter periods than those with long periods in the NASA database. This may be a reason why the orbital periods of the detected exoplanets in this study are shorter than 10 days. Meanwhile, the detection of these new exoplanets, especially the USP exoplanets, can shed light on their kind and expand our views on their planetary systems, which possess different features than our Solar System. Finally, these findings show that artificial intelligence such as deep learning can be an effective technological tool to detect objects of interest in astronomy big data.

KEYWORDS Kepler space telescope, exoplanet discovery, ultra-short period exoplanet, short period exoplanet, big data, deep learning, TensorFlow

Numerical study of low-velocity dust ejection from Phaethon and its connection to the Geminid meteoroid stream

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Interplanetary dust particles (IDPs) give us valuable insight into the constitution and dynamics of the Solar System and also can be used as reference points for exoplanetary research. On Earth, IDPs are delivered to the planet via meteoroid streams (Love and Brownlee 1993), allowing us to get a closer look at the dust particles and their parent bodies. The Geminid stream is one such example. Asteroid (3200) Phaethon is considered as the parent body of the Geminids, and together they form the Phaethon-Geminid stream complex (Whipple 1983; Gustafson 1989). The DESTINY+* mission by JAXA/ISAS will perform in-situ observation of Phaethon in the late 2020s and further advance the science of near-Earth IDPs, and provide information on the dust ejection on Phaethon and even other active asteroids (see, Arai et al. the invited talk).

The dust ejection mechanism of Phaethon and the consequent formation of the Geminids is still not determined. Many dynamical studies were conducted to constrain our understanding of this process to recreate the Geminid stream by numerical simulation, but with varying degrees of success. However, none of them have successfully explained how mm- and cm-sized dust particles can be ejected from the asteroid and end up at the present day on Earth as Geminid meteoroids. In this work, we conducted a numerical simulation of large (> 1 mm) particles from Phaethon, assuming a low-velocity ejection. We will present our results and discuss its implications for the dust ejection mechanism on Phaethon.

* Demonstration and Experiment of Space Technology for Interplanetary voYage Phaethon fLyby and dUst Science

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KEYWORDS active asteroid, Geminids, Phaethon, numerical simulation

FM 8

#2576

DESTINY+ asteroid flyby of Geminid parent Phaethon

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Demonstration and Experiment of Space Technology for INterplanetary voYage with Phaethon fLyby and dUst Science (DESTINY+) is the asteroid flyby mission in JAXA/ISAS small class program. It will be launched in 2024 by a Japanese Epsilon S solid-fuel rocket. It is a joint mission of technology demonstration and scientific observation. The major objective of DESTINY+ is to demonstrate high performance electric propelled vehicle technology and high-speed flyby observation of asteroids. The primary target is (3200) Phaethon and the secondary one in the bonus mission is 2005 UD, which is a likely break-up body from Phaethon. Phaethon is the parent of the Geminid meteoroid stream and an Apollo-type near-Earth active asteroid, ejecting dust upon its perihelion passage, where the surface is heated up to 1000 K due to the small perihelion distance (0.14 au). Mechanism for the dust ejection from the sunburned asteroid has been little known and under hot debate. The scientific objectives of DESTINY+ are (1) flyby imaging of Phaethon to study its geology and dust ejection mechanism, and (2) in-situ analyses of velocity, arrival direction, mass and chemical composition of interplanetary and interstellar dust particles around 1 au, the dust trails, and nearby Phaethon, to characterize cosmic dust deliver to the Earth. The DESTINY+ science payloads include a panchromatic, telescopic camera with a tracking capability (TCAP), a visible-NIR multi-band camera with four bands of 425, 550, 700, 850 nm (MCAP), and a dust analyzer (DDA). DDA is developed by Univ. of Stuttgart, as an international collaboration with DLR. Ground calibration of DDA is performed with German/Japanese joint efforts. International observation campaign for Phaethon was conducted in December 2017, and that of asteroid 2005 UD in October 2018. International observation campaign for stellar occultation by Phaethon was performed in 2019. To further constrain its size and albedo, photometric, polarimetric, and stellar occultation observations of Phaethon were conducted mainly in Japan in October through December 2021.

KEYWORDS flyby, Phaethon, Geminid meteor stream, active asteroid, dust ejection, near Sun asteroid, Apollo-type asteroid

FM 8

#2155

Chemical link between protostellar cores, protoplanetary disks, and primordial objects in the Solar system

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It has long been debated if and how much the Solar system material inherits the composition of interstellar medium. The high D2O/HDO ratio compared with the HDO/H2O ratio in both comet 67P and the central region of protostellar cores indicates the inheritance of water from interstellar ice. The variation of HDO/H2O ratio and molecular abundances among comets, on the other hand, suggests partial modification of ice composition in the disk. Theoretical studies predict active chemical reactions in protoplanetary disks. For example, ion-molecule reactions are triggered by X-ray ionization. Exothermic exchange reactions in cold outer regions and selective photodissociation trigger isotope fractionation. These predictions are now confirmed by high spatial resolution observations of protoplanetary disks, which show that the radial distributions of the column density and isotope ratio vary among molecules. While the line observations probe gaseous molecules, rather than solid material, from which the asteroids and comets are made, gas-phase chemistry and solid-phase chemistry are connected via adsorption and desorption. The coupling of gas-phase and solid-phase chemistry is affected by the dust growth, sedimentation, and turbulence in the disk. The inheritance would be more significant if the dust sedimentation is faster, and turbulence is weaker. Efficient grain growth, radial drift, and dust trap could result in spatial variation of elemental abundances, e.g. C/H and C/O ratio, which is observed in several disks.

KEYWORDS astrochemistry, protoplanetary disks, star formation

FM 8

#1459

Chemical Provenances of Cometary Volatiles

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Comets are thought to be the most pristine relics of the early stages of formation of our Solar System (A'Hearn 2011b, Weissman et al. 2020). More than two dozen molecules are regularly detected in comets (Mumma and Charnley 2011, Bockelée-Morvan and Biver 2017, McKay and Roth 2021). Complex organic molecules have also been detected in several comets, including methanol, formic acid, methyl formate, ethylene glycol, formamide, ethanol, and glycolaldehyde (Bockelée-Morvan et al. 2000, Biver et al. 2015b, Cordiner et al. 2017a). An unprecedented level of chemical complexity has been revealed in the Jupiter-family comet 67P/Churyumov-Gerasimenko by the ESA Rosetta mission (Taylor et al. 2017, Altwegg et al. 2019), including the detection of the simplest amino acid, glycine (Altwegg et al. 2016). The chemical inventory of comets and the isotopic ratios of cometary molecules provide clues to the processes and timing of comet formation. In my talk, I will describe the emerging picture of the origin of cometary volatiles and its implications for the chemical processes during star formation. I will highlight comparative studies of interstellar and cometary molecular inventories such as those of Drozdovskaya et al. 2019. I will focus in detail on the mounting evidence that supports a cold formative past of comets such as the D/H ratios of cometary volatiles (Drozdovskaya et al. 2021, 2022). I will advocate for continued efforts in investigating the chemical composition of comets as they are unique windows to our infant Solar System, including the development of future cryogenic sample return space missions such as AMBITION (Bockelée-Morvan et al. 2021).

KEYWORDS astrochemistry, comets, ALMA, Rosetta, complex organic molecules, D/H ratio, star formation

FM 8
#2157

A brief story of grain growth in young stellar objects

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Terrestrial planets including our own Earth show that sub-micrometer grains of the interstellar medium have grown by more than ten orders of magnitude in size. Then, when and how have such grains grown? These are ones of the fundamental questions to tackle in astronomy. My story starts with the results that dust grains have significantly grown already at the earliest stage of young stellar objects (YSOs). As YSOs evolve, they grow further in circumstellar disks and can move around. A brief story about evolution of YSOs focusing on grain growth is presented with selected results. In addition, how we can study grain sizes of YSOs is addressed.

KEYWORDS grain growth, young stellar objects

FM 8

#2213

Multi-Scale Understanding of C-type Near-Earth Asteroid (162173) Ryugu from Proximity Exploration by Hayabusa2 Spacecraft to Microanalysis of Returned Material

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The JAXA's Hayabusa2 spacecraft explored C-type Near-Earth Asteroid (162173) Ryugu to return the first sample from carbonaceous asteroids, which have long been hypothesized as parent bodies of carbonaceous chondrites. The mission aims to understand the long history of the asteroid and the Solar System from 4.567 billion years ago to the present through multi-scale investigation [1].

The Hayabusa2 spacecraft explored a 1-km-size spinning-top-shaped Ryugu for 17 months. Its low bulk density of 1.19 ± 0.03 g cm−3 and the presence of many boulders suggest that Ryugu is a rubble-pile body [2, 3]. The surface has a low geometric albedo (~0.02) [3], and shows a weak but ubiquitous 2.72-μm O-H vibration absorption feature indicating the presence of hydrous minerals [4]. The MASCOT lander and two MINERVA-II rovers investigate morphology and physical properties of surface boulders and pebbles at multiple surface locations [5-7].

The spacecraft made two landing operations for sample collection, the latter of which was made near the spacecraft-made artificial crater to collect the impact ejecta [8]. The sample was successfully delivered to the Earth in December 2020. Because spectroscopic and morphological features of returned sample are consistent with the spacecraft observation, the returned sample well represents the Ryugu's surface material [7, 9, 10]. A fraction of Ryugu sample (0.3 g in total) was allocated to the Hayabusa2 initial analysis team for science-oriented detailed investigation from chemical (both inorganic and organic), mineralogical, and petrological perspectives. This presentation will focus on multi-scale understanding of Ryugu through the proximity observation of the asteroid and the analysis results of Ryugu sample.

[1] Tachibana et al. (2014) Geochem. J. 48, 571. [2] Watanabe et al. (2019) Science 364, 268. [3] Sugita et al. (2019) Science 364, eaaw0422. [4] Kitazato et al. (2019) Science 364, 272. [5] Jaumann et al. (2019) Science 365, 817. [6] Grott et al. (2019) Nat. Astron. 3, 971. [7] Tachibana et al. (2022) Science 375, 1011. [8] Arakawa et al. (2020) Science 368, 67. [9] Yada et al. (2021) Nat. Astron. 6, 214. [10] Pilorget et al. (2021) Nat. Astron. 6, 221.

KEYWORDS C-type asteroid, Hayabusa2, Solar System

FM 8

#493

Observing small bodies from light points to micro-particles

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The knowledge of the physical and compositional properties of asteroids, comets, transneptunian objects, is fundamental to understand the processes that occurred in our solar nebula as well as in the other planetary systems.

In the last century, small bodies began to no longer appear as starlike points of light in our telescopes, but to be resolved worlds with measurable sizes, shapes, and surface morphologies. Many of these objects, particularly transneptunians, continue to be on the limit of observability by the today ground-based telescopes.

By the end of the XXth century, space exploration and advances in remote observations have triggered major progress in our understanding of the small bodies, which appear more complex and fascinating than ever. More than 20 small bodies, all different from one another, have been the targets of past space missions. Starting in 1986, when the Giotto ESA mission was the first to take a close look at a comet nucleus, passing through the inner coma of 1P/Halley, many others followed.

On the last decade the ESA mission Rosetta had a successful rendezvous with the comet 67P/Churyumov-Gerasimenko and delivered a surface science package, the NASA mission New Horizons arrived in an extraordinary short time to Pluto system, visiting also with a fly-by the small TNO (486958) Arrokoth. The JAXA Hayabusa, Hayabusa2, and NASA OSIRIS-REx missions allowed to analyze the respective target asteroids at different scales up to analyze at micro-nano scales the returned sample.

All together these missions have revolutionized our understanding of the small bodies. The obtained results allowed us to test many ground based techniques and the lessons learned will help to better characterize our continuing investigations of the small body population. A short non exhaustive overview of the principal results will be presented.

KEYWORDS small bodies, space missions

e-Posters

FM 8

#3419

Thermal design of a suite of two optical cameras mounted on a rover for lunar mid-latitude exploration

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We provide thermal modeling and design of GrainCams which consists of optical systems mounted on a lunar rover. GrainCams is a suite of two light field cameras, SurfCam and LevCam, designed to study the characteristics of the upper lunar regolith and levitated dust grains on the Moon. The Commercial Lunar Payload Services (CLPS) manifest selection of GrainCams is under consideration, and if successful, the payload will perform lunar surface exploration in the mid-2020s. Achieving a viable thermal design is essential for the success of the mission despite the extreme lunar thermal environment. Our thermal design, thus, employs both passive and active thermal control techniques: thermal insulation blankets, surface control of thermal radiation, radiators with a specially designed inclination angle, and heaters. We first completed the radiator design that satisfies the temperature requirements in the worst hot case through thermal analysis and then calculated the required heater power with the radiator design in the worst cold case. The design of SurfCam also satisfies the temperature requirements for the observation (deployed) mode when the instrument approaches the lunar surface to make close-up observations as well as the stand-by (stowed) mode.

KEYWORDS Lunar surface payload, Thermal analysis, Thermal design, Lunar rover

FM 8

#3406

High-Resolution Mid-Infrared Observations of Planetary Rings from the Ground

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We present mid-infrared (MIR) high spatial resolution images of Saturn's rings obtained with the Subaru Telescope as an example of observations of solid particles around a planet. The temperature profiles of the rings were estimated from the MIR spectral energy distributions (SEDs) of the C, B, and A rings and the Cassini Division in 2008 composed from the images. The achieved spatial resolution of the profile is 4000 km, almost comparable to the one by Cassini/CIRS, and, to our best knowledge, seems the highest ever reported from ground-based observations. We found that the C ring and the Cassini Division were warmer than the B and A rings in 2008, which could be accounted for by their lower albedos, lower optical depths, and smaller self-shadowing effect. We also found that the radial profile of the MIR emission contrast of Saturn's rings in 2008 was the inverse of that in 2005. This temporal variation is probably caused by seasonal changes in the elevations of the Sun and observer above the ring plane as varying angles will lead to differing filling factors and temperatures of the particles in the rings.

KEYWORDS Planetary Rings, Infrared Observations

FM 8

#3402

Introduction to GrainCams for Lunar Surface Exploration Mission

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GrainCams aim to understand characteristics of the uppermost regolith and levitating dust on lunar surface. GrainCams will operate on lunar surface with a rover. It has two light field cameras that are surface camera (SurfCam) and levitating dust camera (LevCam). The main objective of SurfCam and LevCam is to obtain three dimensional images of microscopic structure of the uppermost regolith and levitating dust grains, respectively. Lunar regolith microstructure, usually called 'fairy castle structure', is significant to understand regolith properties such as light scattering, thermal emissivity, albedo and so on. However, it is not well-known yet. SurfCam will take light field images of the upper few millimeters of the regolith with various region near the landing site. The data obtained by SurfCam will provide the enigmatic shape of the fairy castle structure and will improve the photometric and thermal emissivity characteristics of airless bodies. SurfCam is a x3 microscope with a 30 mm aperture and its spatial resolution is smaller than 12 μm. The micro lens array employed by SurfCam contain 409 × 341 lenses.

The scientific objective of the LevCam is to observe the motions of levitating dust grains with sizes of ~ 1 μm. LevCam is also a light field camera system. Thus, LevCam will measure three dimensional positions and speeds of levitating dust grains, which can provide the density of dust grains ~ 10 cm above the lunar surface and the strength of the electric fields near the lunar surface. LevCam has a 70 mm aperture main lens and its working distance is around 1 m from the optics. The micro lens array contains 48 × 45 micro lenses.

The GrainCams is expected toimprove the our knowledge of the electrostatic environments of the lunar surface.

KEYWORDS Moon, exploration, regolith, instrument

FM 8

#3315

Korea's Scientific Payloads on the Lunar Surface through the NASA/CLPS initiative

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Korea Astronomy and Space Science Institute (KASI) is developing four payloads, GrainCams, LVRAD, LSMAG, and LUSEM, to make scientific measurements on the lunar surface to be onboard Commercial Lunar Payload Services (CLPS) landers based on the KASI-NASA Exploration Working Group. Korea's Ministry of Science and ICT (MSIT) supports the development, mission operation, and data analysis processes.

GrainCams has two light-field cameras, SurfCam and LevCam. SurfCam will take light-field images of the microscopic structure of the uppermost regolith at several different places on the Moon. LevCam will detect the regolith grains levitating and lofted above the surface and take measurements of their motions. These phenomena are not reproducible on Earth nor preserved via a sample return mission.

LVRAD is a suite of instruments to measure the radiation environment on the lunar surface using a Particle Dosimeter and Spectrometer (PDS), Tissue-Equivalent Dosimeter (TED), and Epithermal and Fast Neutron Spectrometers (NS-E and NS-F, respectively).

LSMAG will measure the magnetic field on the lunar surface using two fluxgate magnetometers on a 1-m boom to model the strength and direction of dipole sources lie buried nearby the lander, possibly in collaboration with other magnetometers onboard orbiters of different altitudes such as ones onboard ARTEMIS, Korean Pathfinder Lunar Orbiter (KPLO), and so one.

LUSEM consists of two pairs of the two solid-state telescopes (SST) to detect high-energy particles of tens keV to tens MeV on the lunar surface. Each pair consists of a nadir- and zenith-viewing SST to take measurements of the incoming high-energy particles and the reflected ones simultaneously.

LUSEM will be onboard a Nova-C lander in Intuitive Machines to visit the Reiner Gamma swirl as a part of IM-3 in 2024. The embarkment of the other payloads is under discussion. All the science, technology, and experiences built up from this project will also help Korea's lunar landing mission.

KEYWORDS Moon, exploration, lander, CLPS

FM 8

#3302

Asymmetric space weathering in northern and southern hemispheres on the Moon

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Space weathering on the Moon is generally known to be dominated by solar wind irradiation and micrometeorite impacts. They change the lunar regolith to optically mature by altering its compositions and spectral properties. The wall quadrants of lunar craters have the advantage of studying the optical maturity (OMAT) difference caused by the solar flux difference between opposing quadrants. The wall quadrants had been exposed on the surface for the same duration but the quadrants facing each other have different incident angles of the space weathering particles depending on the location.

Previous studies have found latitudinal and longitudinal dependencies of optical properties on the lunar surface. Following Sim et al., who studied the space weathering asymmetry inside lunar craters, here we apply the extended lunar crater database (Robbins et al.) to consider more and smaller craters. A total of 26,802 craters ranging from 2 to 150 km in diameter are used, more than 10 times the 1,872 in the previous study. We reproduce the dependencies with the improved processes—finding the rim, defining the inner structure, and dividing wall quadrants of the craters.

Furthermore, we find that the OMAT difference between the equator-facing (EF) and pole-facing (PF) walls has opposite trends in the northern and southern hemispheres at lower latitudes. Below 25 degrees, the EF wall is more mature than the PF wall in the northern hemisphere, but it is the opposite in the southern hemisphere. Unlike previously known, the hemispheres seem not to be symmetrically affected along the ecliptic plane. In particular, the degree of weathering on the EF and PF walls is significantly asymmetric near the equator. We speculate that this unexpected result is caused by asymmetric impacts of meteoroids in the northern and southern hemispheres on the Moon.

KEYWORDS The Moon, Lunar science, Lunar surface, Lunar craters, Planetary science, Surface processes

Grain Growth and Dust Segregation Revealed by Multi-wavelength Analysis of the Class I Protostellar Disk WL 17

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Disks around protostars are the natal place of planets. The first step toward planet formation is grain growth from (sub-)micrometer to millimeter/centimeter sizes. Grain growth has been reported not only in Class II protoplanetary disks but also in Class 0/I protostellar envelopes. However, such rapid grain growth is little known on the protostellar disk scale. Here we present the result from the ALMA Band 3 (3.1 mm; 97.5 GHz) and 7 (0.87 mm; 350 GHz) archival data of the Class I protostellar disk WL 17 in the ρ Ophiuchus molecular cloud. Disk substructures are found in both bands as reported in previous studies but they are different: while a central hole and a symmetric ring appear in Band 3, an off-center hole and an asymmetric ring are shown in Band 7. Furthermore, we obtain an asymmetric spectral index (α) map with a low mean value of 2.28 ± 0.02, indicative of rapid grain growth and dust segregation on the protostellar disk scale. Radiative transfer modeling demonstrates that 10 cm-sized large grains are symmetrically distributed, whereas 10 μm-sized small grains are asymmetrically distributed, and that the disk is massive and gravitationally unstable. We suggest a single Jupiter-mass protoplanet formed by gravitational instability as the origin of the rapid grain growth and dust segregation revealed in WL 17.

KEYWORDS radio astronomy, star formation, planet formation, protostellar disk, grain growth

FM 8
#2928

Harnessing the Yarkovsky effect to measure densities of probable M-type near-Earth asteroids

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The Asteroid belt must contain some part of metallic asteroids, whose material formed in the cores of differentiated planetesimals, liberated in disruptive collisions, and now routinely falls on the Earth in the form of iron meteorites. Still, we can point out at very few asteroids whose metallic composition is more or less certain.

Most remote sensing techniques only probe the surface properties of an asteroid. The consensus is that asteroids of the taxonomic type M are the most probable candidates for metallic asteroids. But do asteroids with seemingly metallic surfaces also have metallic interiors? The most effective way to answer this question is by measuring asteroid densities.

Densities of small near-Earth asteroids can be measured via their Yarkovsky effect, which is a secular change of an asteroid orbit due to the asymmetric emission of thermal radiation. The Yarkovsky effect has been observationally detected for about 250 near-Earth asteroids. Comparing these results to theoretical predictions from the thermophysical modeling results in density estimates for the asteroids. On the observational side, the number of detected Yarkovsky drift is expected to increase dramatically due to the Gaia data. Still, on the theoretical side, a simple and robust theory for the Yarkovsky effect is needed to analyze these data.

Here, we present such a mathematical model of the Yarkovsky effect. It accounts for the asteroid's oblateness and thermal properties but does not require such unaccessible information as the detailed asteroid shape. We test this model and create a Monte Carlo program that simulates the density of an asteroid given the uncertainties in the asteroid’s Yarkovsky drift rate, thermal inertia, shape, pole, and radius.

We use the proposed method to measure densities of a dozen NEAs, whose optical, thermal and radar properties are close to those of the M-type asteroids Resulting densities for all the studied asteroids cluster around 1-2 g/cm^3, indicating no presence of large quantities of metal in their interiors.

KEYWORDS Asteroids, Near-Earth objects, Thermophysical modelling, Yarkovsky effect

FM 8

#1974

Color indexes survey of NEOROCKS Near Earth Objects targets

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Asteroids are composed by remnant material, mostly unmelted, from the formation of our Solar System. Near-Earth Objects (NEOs) physical characterization is important into understanding of chemistry of planetary system nebula.

European efforts formalized into the NEOROCKS program imply the improvement knowledge on the physical properties of the NEOs population, the implications for their origin and evolution, and the topics related to planetary defense.

Color indexes survey of NEOs was started in 2020 as a regular program of observations implying a minimum of 20 nights each year. Observations are performed in France at the Observatoire de Haute Provence and Observatoire de Pic du Midi. Two assets are used, namely 1.20m telescope and 1.05m telescope respectively.

The NEOs targets covered preferentially the Potential Hazardous Asteroids (PHAs) population. Johnson B and V, Cousins R and Gunn I filters are used for their characterization. Between 2020 and January 2021, color indexes were computed for 81 objects. Among these, 38 asteroids belong to the PHAs category. Data analysis, statistics, and taxonomic classification are presented.

* NEOROCKS team: D. Perna, E. Mazzotta Epifani, A. Cellino, A. Dell'Oro, V. Petropoulou, S. Ieva, E. Perozzi, M. Lazzarin, F. Laforgia, E. Frattin, B. Carry, C. Snodgrass, A. Rozek, P. Pravec, J. Licandro, J. Deleon Cruz, M. Popescu, H. Medeiros, F. Pina Caballero, J. A. Gonzalez Abeytua, J. Nomen, A. Mediavilla Garay, F. Bernardi, Neorocks Resolvo

KEYWORDS Near-Earth Objects, observations, color index, statistics

FM 8

#2243

Early activity in Jupiter Trojans after being captured and their influence on the surface colors

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Jupiter Trojans came from an outer primordial planetesimal disk to the present location during a dynamical instability. The changed thermal environments might have altered the thermal and mechanical structures of the Trojans. Using a numerical simulation, we examined the evolutionary processes of the Trojans in the early stage after their migration. When the initial phase of water ice is amorphous, comet-like activities occur at the present location of the Trojans regardless of other parameters like dust to ice ratio and dust thermal conductivity. It implies that a crystallization mechanism after the migration caused the activity that possibly changed the surface colors as suggested for the active Centaurs. It is expected that we can understand the evolutionary processes of Jupiter Trojan and their influence on the surface colors.

KEYWORDS Trojan asteroids, Kuiper belt objects, Comets, Planetary surface

FM 8

#1838

The role of continents on the global surface temperature of an Earth-like planet

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One of the requirements for habitability is liquid water. Its presence depends strongly on temperature and this, in turn, is determined by the distance between the planet and its host star. However, there are also other factors that are less studied such as the geodynamic and geophysical environments. These environments include many factors that could modify the temperature of a planet, such as the composition of its atmosphere, or the continental distribution, the latter being the focus of this work. We use Planet Simulator (PlaSim), a climate model of intermediate complexity for the Earth and other planets, to study the effect in temperature of stepwise change of continental area with respect to that of Earth. Preliminary results show that the global surface temperature varies depending on the position of each continent removed, although it has a clear tendency to decrease with decreasing in the amount of total continental land.

KEYWORDS Global surface temperature, Continental land, Earth-like planet, Planetary simulation

FM 8

#1419

2-micron Mapping of the Jovian Polar Haze using Juno/JIRAM data

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We have analyzed 2-micron spectro-images of the polar haze of Jupiter, which have been obtained by the Jovian Infrared Auroral Mapper (JIRAM/Juno), in order to study polar haze distributions. The polar haze may be actively formed by auroral particle precipitations on the polar regions of Jupiter. For the investigation of this formation scenario, the first step is to determine the morphology of the polar haze distribution. We have constructed detailed contour maps of the polar haze by selecting specific 2-micron spectral ranges, where the polar haze most prominently shows; and we will present our preliminary results.

KEYWORDS Jupiter, Haze, Juno, JIRAM, Infrared, Spectroscopy, Aurora

FM 8
#862

Atmospheric properties of sub-Neptune atmospheres: TOI-270 system

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We investigate the potential for the James Webb Space Telescope (JWST) to detect and characterize the atmospheres of sub-Neptunian exoplanets in the TOI-270 system. Sub-Neptunes are considered more likely to be water worlds than gas dwarfs. We model their atmospheres using three atmospheric compositions – two examples of hydrogen-dominated atmospheres and a water-dominated atmosphere. We then simulate the infrared transmission spectra of these atmospheres for JWST instrument modes optimized for transit observation of exoplanet atmospheres: NIRISS, NIRSpec, and MIRI. We then predict the observability of each exoplanet's atmosphere. TOI-270c and d are excellent targets for detecting atmospheres with JWST transmission spectroscopy, requiring only 1 transit observation with NIRISS, NIRSpec, and MIRI; a higher signal-to-noise ratio can be obtained for a clear H-rich atmosphere. Fewer than three transits with NIRISS and NIRSpec may be enough to reveal molecular features. Water-dominated atmospheres require more transits. Water spectral features in water-dominated atmospheres may be detectable with NIRISS in two or three transits. We find that the detectability of Ammonia, which is a unique biosignature in atmospheres rich in Hydrogen (Seager et al. 2013), would only require one transit with NIRISS/SOSS to be detected at higher SNR. TOI-270c and d are promising sites for follow-up atmospheric characterization with JWST.

KEYWORDS planets (TOI-270 system), atmospheres, composition, JWST

FM 8

#730

Asteroid Polarimetric-Phase Behavior in the Near-Infrared

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Polarimetry offers us a unique way of characterizing asteroid surfaces and probing their mineralogical makeup. We present our first results from a survey of asteroid polarization-phase curves using the WIRC+Pol instrument on the Palomar 200" telescope. We find that C-complex objects show nearly identical behaviors at J and H bands as they do at visible wavelengths. However, S-complex asteroids show a significant shift in their polarization-phase curves, indicative of a change in refractive index of the surface material from visible to J and H bands. Future work will investigate the behaviors of specific objects and taxonomic classes.

KEYWORDS asteroids, polarimetry, near-infrared

FM 8

#673

The light field camera simulation based on ray-tracing for CLPS/ GrainCams

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In general, Light Field Camera (LFC) can obtain spatial and directional light information. It can be designed by adding an appropriate microlens array (MLA) to a general camera system. In order to design a custom light field camera for scientific purpose, one need to find appropriate trade-off calculations between spatial and directional resolutions through image test with various diameter sizes of microlens. Custom MLAs can be rather expensive, thus an accurate light field camera simulation could allow to reduce production costs. In this study, we simulated virtual observation images based on ray-tracing for CLPS/GrainCams composed of two light field camera instrument package, SurfCam and LevCam, designed to understand the environment of the lunar surface.

KEYWORDS

FM 8

#582

Thermal Escape of Hydrogen and Helium in the Solar System

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The effective temperature of the Sun is about 5780 K, far less than the temperature (= 1.552 × 107 K) needed for most Hydrogen to escape from the Sun's gravity by thermal activation. It is therefore easy to anticipate that all the Hydrogens are gravitationally bound to the Sun. In fact, only a minute leakage of Solar Hydrogen occurs from the Solar Corona in a form of Solar wind. For Jupiter, the average speed of thermally activated molecular Hydrogen (1.889 km s–1) or Helium (0.944 km s–1) is much smaller than the escape velocity (= 60.2 km s–1). That is why Hydrogen and Helium are hardly lost from the Jupiter's surface. On the other hand, temperatures in the Earth's upper thermosphere ranges from 800 to 2300 K, which is comparable to that (= 5086 K) calculated from molecular activation energy of Hydrogen. Then, it is natural to expect thermal escape of Hydrogen and Helium from Earth's atmosphere. According to thermodynamic statistics, a significant proportion of molecules can escape from the uppermost layer of the planetary body when the ratio of escape velocity to thermal activation velocity is confined within six. As a result, Jovian planets retained nearly all the atmospheric constituents while very little leakage of Hydrogen and Helium into space occurred.

KEYWORDS Solar System, Atmosphere, Hydrogen, Helium, Gravity, Energy

FM 8
#581

Resolution of Wobble Method for Detecting Planets

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The center of mass (CM) is a unique point where the mean of the masses factored by their distances from the known reference position. The CM is analogous to the mass–balance with respect to a pivot point of the seesaw. Using the CM relation, magnitude of wobble of the Sun exerted by the Jupiter was estimated as 7.5×10^8 m. Such wobble generates a Solar motion of 2 m s^{-1}. Similarly, the wobble of the Earth produced by the Moon was determined as 4.7×10^6 m, induces radial velocity of Earth with 6.0×10^{-6} m s^{-1}. The wobble of the Neptune produced by the Triton was 7.4×10^4 m, responsible for the small radial velocity of Neptune (7.5×10^{-6} m s^{-1}). The maximum angular diameter of the wobble would be about 500 micro arc sec at 10 pc for the Jupiter–Sun system. Magnitude of Solar wobble produced by terrestrial planets are less than 1% to that produced by Jupiter. For instance, magnitude of Solar wobble produced by Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune are 1.0×10^{-3} m s^{-1}, 1.4×10^{-2} m s^{-1}, 1.4×10^{-2} m s^{-1}, 1.0×10^{-3} m s^{-1}, 2.0×10^{0} m s^{-1}, 4.4×10^{-1} m s^{-1}, 4.7×10^{-1} m s^{-1}, and 4.5×10^{-1} m s^{-1}, respectively.

KEYWORDS Planet, Solar System, Wobble, Earth, The Moon, Sun

FM 8

#579

Brecciation and Magnetic Lock-in of Chondrites

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To decipher erratic magnetic behavior of chondrites, a suite of rock magnetic experiments including alternating–field demagnetization, thermal demagnetization, and temperature dependence of anhysteretic remanent magnetization and saturation isothermal remanent magnetization were carried out. While Kamacite ($Fe_{0.9}Ni_{0.1}$) displayed virtually no remanent magnetization, stable ancient planetary magnetic field was retrieved from tetrataemite ($Fe_{\cancel{0.6}}Ni_{0.4}$). Directional scatters in higher unblocking fractions for tetrataenite (500–550°C) were probably originated from the first episode of brecciation occurred in a presence of a planetary magnetic field. The second shock–related episode of metamorphic event occurred under the influence of a planetary magnetic field with a peak temperature ~500°C. It is possible that the second shock–related event induced a partial thermal overprint. A subsequent third shock–induced disturbance modified existing magnetic signals. Of course, the second and third events can be simplified as a single pervasive shock–induced magnetic lock–in process.

KEYWORDS Chondrite, Magnetism, Solar System, Kamacite, Tetrataenite

Results of Photometric Observations of Comet P/2019 LD2 at the Sanglokh Observatory

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Optical observations of short-period comet P/2019 LD2 (Atlas) were carried out over five nights in August 2020 at the Sanglokh International Astronomical Observatory of the Institute of Astrophysics of the NAST with the Zeiss-1000 telescope using a broadband filter R. Based on data from observations, the following physical characteristics of the comet were obtained:

(1) Apparent magnitudes mR by measurements of each night of observations; (2) Absolute magnitude mR(1,1,0) = 11.42± 0.03m; (3) Parameter of dust production Afρ about 250±6.5 cm (at ρ=4.05"); (4) Estimate of the upper limit of the radius of the comet's nucleus rmax=6.1± 0.1 km at albedo A=0.12; (5) Isophotes of the comet were constructed, demonstrating the distribution of brightness along the tail; (6) Finson–Probstein diagrams of the inner and all visible part of the comet's dust tail were constructed and its structure, namely the distribution of dust particles by size and by the time of ejection from the surface of the nucleus, was found. It was shown that large particles over 100 μm in size are dominant in the inner regions of the dust tail; (7) Photometric data indicate that during the monitoring period the comet was in a stage of slightly increased cometary activity, associated mainly with the recent passage of the perihelion. During the observations, the comet's heliocentric distance was 4.591–4.593 AU. At such distances, less than the so-called "snow line", to some extent, the typical processes responsible for normal cometary activity can still acting, namely, solar heating of the surface, sublimation of surface frozen volatile components, dust emission and the formation of a coma and tail; (8) The comet's current orbit indicates that the comet is in the transition from Centaurs to Jupiter family comets. A slightly increased value of Afρ compared with other comets of the Jupiter family may indicate a previous long stay of the comet in the outer regions of the Solar system.

KEYWORDS comet, photometry, brightness, diameter, dust production, distribution of dust particles, transition stage

FM 9

Stellar Synthetic Spectra to Study Stellar Populations in the Gaia Era

Invited & Contributed Talks

FM 9

#1325

Self-Consistent Stellar Chemical Abundance Measurements: From Near to Far, High to Low (Resolution)

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The next decade will see increasingly powerful and highly-multiplexed spectroscopic facilities (e.g., 4MOST, WEAVE, DESI, PFS, MSE, ELTs) capable of measuring the spectra and chemical compositions of ~50 million resolved stars in the Milky Way and Local Group. The majority (75%) of these spectra will be obtained at low-resolution (R < 10000), where the severe blending of absorption lines necessitates full spectral modelling and robust synthetic stellar spectra to precisely and accurately measure chemical abundances. These combined spectral datasets will also feature a high degree of heterogeneity (varying S/N, wavelength coverage, resolution), which introduces a number of additional challenges in deriving consistent and reliable stellar labels. Here, I quantify biases and uncertainties in stellar label recovery as a function of S/N and spectral resolution by degrading and self-consistently applying full spectral modeling to initially exquisite Keck/HIRES spectra (R > 50000, S/N > 100) of 11 red giants in MW globular cluster M15. In doing so, I identify several specific challenges and successes of using synthetic stellar spectra to bridge the gap between the high-resolution stellar spectroscopy characteristic of past MW surveys (e.g., APOGEE, GALAH) and the low-resolution stellar spectroscopy required for large-scale galactic and extragalactic surveys.

KEYWORDS Stellar Spectroscopy, Chemical Abundances, Milky Way, Local Group

FM 9

#504

How Many Elements Matter

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Ambitious Galactic spectroscopic surveys such as Gaia-ESO, APOGEE, and GALAH have obtained high-resolution, high signal-to-noise ratio spectra of hundreds of thousands of stars, spanning large swaths of the Milky Way. The high-resolution surveys provide detailed chemical fingerprints for each program star, typically measuring 15-30 elements per star. A key question to these surveys is how many of these elements actually contain independent information. It has long been recognized that the ratio of alpha-elements to iron peak elements is an important dimension of stellar abundance variation in addition to overall metallicity. However, the evidence on variations beyond the metallicity and alpha-enhancement is mixed. Some studies of stars' multi-element abundance distributions suggest at least 5-7 significant dimensions, but others show that many elemental abundances can be predicted to high accuracy from [Fe/H] and [Mg/Fe] (or [Fe/H] and age) alone. In this talk, I will reconcile these seemingly contradictory results. I will show that both propositions can be, and are, simultaneously true. In particular, I will discuss, although one could infer elemental abundances to high accuracy with only [Fe/H] and [Alpha/Fe] elements, residual abundances can display clear correlations between other elements, which signal cannot be explained by only two elements. I will demonstrate that cross-element correlations are a much more sensitive probe of hidden structure than dispersion, and they can be measured precisely in a large sample even if star-by-star measurement noise is comparable to the intrinsic scatter. In short, many elements have an independent story to tell, even for the "mundane" disk stars and elements produced by core-collapse and Type Ia supernovae. The only way to learn these lessons is to measure the abundances directly, and not merely infer them.

KEYWORDS Stellar Spectroscopy, Elemental Abundances, Star Formation, Interstellar Medium, Stellar Yield

FM 9
#1408

Galactic Archaeology with Spectra from the GALAH Survey

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The Galactic Archaeology with HERMES (GALAH) Survey is a leading stellar spectroscopic survey of the Milky Way. At the end of this year, we will likely reach the milestone of observing high-resolution optical spectra of 1 million stars! Analysing these spectra comes with enourmous challenges. As the main analyst of the spectroscopic data, I will elaborate on the many lessons that we have learned throughout the last years: What information is (or is not) included in spectra for different stellar types? How can we overcome shortcomings in both synthetic spectra and the analysis of imperfect observations. How should we treat peculiar objects/spectra in our data? What systematic trends and selection biases do we have to be aware of? The GALAH Survey is pioneering the use of 1D non-LTE spectrum analysis on the scale of millions of stars. I will present our previous, current, and future approaches on how to analyse spectra fast, but still precisely and accurate. Finally, I will give a view on the latest data and analysis products that will be published in GALAH DR4.

KEYWORDS

FM 9
#2113

Old super-metal rich stars in the solar vicinity: from where did they come?

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We report the identification of a set of peculiar stars in the solar vicinity that have chemical characteristics of the thin disc but dynamical properties closer to the thick disc. These are old, super metal-rich dwarf stars with orbits of low eccentricity (e$\lesssim$0.2) that reach a maximum height from the Galactic plane between ~0.5-1.5 kpc. This presentation will discuss their chemo-dynamical properties to understand their potential origins. We use the data from the internal data release 6 of the Gaia-ESO Survey. We select stars observed at high resolution for which abundances of more than 18 chemical elements are available. We apply a hierarchical clustering algorithm to group the stars according to their chemical abundances. Orbits were integrated using astrometric data from Gaia and radial velocities from Gaia-ESO. Stellar ages were estimated using isochrones and a Bayesian method. According to their chemical properties, this set of super metal-rich stars can be arranged into five subgroups. Four seem to follow a chemical enrichment flow, where nearly all abundances increase in lockstep with Fe. The fifth group shows different chemical characteristics. All the subgroups have the following features: ages of the order of 10 Gyr, solar or sub-solar [Mg/Fe] ratios, high values of maximum height from the Galactic plane, low eccentricities, and no metallicity gradient with guiding radius (which varies between 6 to 9 kpc for the majority of the stars). The high metallicity of our stars is incompatible with a formation in the solar neighbourhood. Dynamical heating caused by the bar and spiral arms is expected to induce the migration of such metal-rich stars from the inner Galaxy to the solar region. Their dynamic properties agree with theoretical expectations of stars that suffered radial migration. Hence, we suggest that this population originated in the inner regions of the Milky Way and later migrated to the solar neighbourhood. These results are presented in Dantas et al. (submitted).

KEYWORDS Galaxy: abundances, Galaxy: evolution, Galaxy: kinematics and dynamics, Galaxy: stellar content, Stars: abundances

FM 9

#1116

Empirical Calibration of Synthetic Stellar Spectra based on Large Photometric Surveys

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Accurate relations of stellar colors and magnitudes are essential ingredients for constraining fundamental stellar parameters and chemical composition based on large photometric survey databases. As one such effort, an empirical approach to calibrate theoretical isochrones can be used to improve photometric metallicity estimates for a large number of stars in the Milky Way. Here, we devise a method of calibrating model fluxes in theoretical stellar spectra, as opposed to making corrections on individual color indices in the models in our previous work. The current approach relies on a comparison with multi-wavelength optical and near-infrared color-Teff relations derived from Galactic cluster sequences, Gaia's double sequence, and a sample of spectroscopic data in SDSS, using standard-star photometry in the literature and photometric data in a number of broad- and medium-band filters from SDSS, SMSS, and APASS. We derive mean flux deviations as a function of wavelength at 4000 < Teff < 7000 K and -3.0 < [Fe/H] < +0.4, and present metallicity distributions of stars observed in these surveys based on the calibrated models. We discuss the extensibility of the calibrated synthetic spectra, which enable accurate predictions of stellar magnitudes for filter passbands in upcoming photometric surveys, including the LSST.

KEYWORDS Synthetic spectra, Stellar isochrones, Synthetic colors, Large Surveys, Color-Teff relation, Metallicity distribution, Stellar populations

FM 9

#2144

Stellar Spectroscopy for Cosmology: Prospects & Challenges with Late-Type Stars as Standard Candles

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The intrinsic brightness of the tip of the red giant branch (IR-TRGB) makes it a powerful distance indicator (M(H)~ - 6 mag) and coupled with the near-ubiquity of red giant stars in galaxies of a wide-range of morphological types, the IR-TRGB is poised to be a prime tool to address some of the biggest challenges in 21st century cosmology. In this talk, I will explore the limitations of current synthetic and empirical stellar libraries as they directly contribute to our understanding of the IR-TRGB. More specifically, in accurately predicting the impacts of chemical abundance and age on the shape of the IR-TRGB for composite stellar populations. I will demonstrate how bolometric corrections, derived both semi-empirically and theoretically, fundamentally limit stellar population predictions. I will demonstrate progress toward understanding these issues with empirical spectral libraries, but also demonstrate their limited abilities to probe cool, luminous stars. Ultimately this problem is one of lacking key foundational data with which to compare. To this end, I will describe an on-going program in ground and space aimed at producing high signal-to-noise empirical data for stars in the Large and Small Magellanic clouds as well the development of a small, infrared facility to obtain high signal-to-noise data on nearby bright stars that are not included in 2MASS. I hope to facilitate discussion on what additional obsevational data is needed to improve our understanding of late-type giants.

KEYWORDS Spectroscopy, Photometry, Standard Candles, Giants, Stellar Populations, Infrared

FM 9
#1086

IGRINS high-resolution near-infrared spectroscopy of globular cluster candidates toward the Galactic bulge

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Globular clusters (GCs) play an important role to study the formation and evolution history of the Milky Way. However, only a small number of GCs were found at the low-latitude field, and their nature was poorly studied. Recently, an increasing number of stellar clusters were discovered in the bulge from Gaia and VVV surveys. In order to investigate the new GC candidates, we performed near-infrared high-resolution spectroscopy of stars toward the Galactic bulge using the IGRINS instrument at the Gemini-South telescope. We selected 15 and 10 target stars near Camargo 1103 and Camargo 1106, respectively, which have been recently reported as metal-poor GC candidates in the bulge. Contrary to the classical approaches used in optical spectroscopy, we determined stellar parameters from a combination of line-depth-ratios and the equivalent width of a CO-line. The stellar parameters of the stars follow the common trends of nearby APOGEE sample stars in a similar magnitude range. We also determined the abundances of Fe, Na, Mg, Al, Si, S, K, Ca, Ti, Cr, Ni, and Ce through spectrum synthesis. There is no clear evidence of a grouping in radial velocity-metallicity space that would indicate the characterisation of either object as metal-poor GCs; however, such a null-detection could also be due to an inefficient and emphasises the difficulties in dealing with crowded, extinct areas. We also note discrepancies between the abundances of Al, Ca and Ti when derived from the H- vs the K-band spectra. Although the cause of this discrepancy is not clear, the effects of atmosphere parameters or non-local thermodynamic equilibrium are suspected. Our approaches and results clearly demonstrate that IGRINS spectroscopy is a very useful tool to study stars toward the Galactic bulge and to characterise or refute obscure GC candidates.

KEYWORDS Techniques: spectroscopic, Stars: abundance, Galaxy: bulge, globular clusters: general, Infrared: stars

Astronomy for All
Busan 2022

FM 9

#2895

A grid of synthetic spectra for the study of multiple populations in globular clusters

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Globular Clusters (GCs) are challenging and fascinating astronomy objects. Once understood to be simple stellar populations, it is now known that stars in massive GCs present chemical variations not expected by the current theoretical predictions. In this work, we have calculated stellar spectra to study the integrated properties of GCs, considering three iron metallicities and two generations of stars — a primordial one following the pattern of galactic halo stars and a second one with anti-correlated CN-ONa abundances. We show that the modelled stellar population spectra present signatures of the CN-ONa anti-correlations, thus affecting our interpretation of the integrated spectrum of a GC and the Lick indices. Before applying our models to extragalactic environments, where only the integrated spectra of GCs can be accessed, we are calibrating our stellar spectra grid to a sample of metal-poor empirical spectra drawn from the X-Shooter Library (XSL). Also, we present the first results of the comparisons between the synthetic and observed XSL spectra, showing how the quality of the fits are affected by the main stellar parameters and wavelength regions. This will allow us to construct a more reliable grid of synthetic spectra to study the multiple populations on GCs.

KEYWORDS Globular Clusters, Galactic Astrophysics, Extragalactic Astrophysics, Stellar Populations, Stellar Clusters, Synthetic Spectra, Model Atmospheres

FM 9
#381

Al-Wardat's Method for Analyzing Binary and Multiple Stellar Systems

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The astrophysical studies showed that there is no direct method to estimate the fundamental parameters of the individual components of binary and multiple stellar systems (BMSSs). So, computational methods are the only way to reveal the mysteries of these systems.

Introduced in 2002 for the first time, Al-Wardat's method for analyzing BMSSs proved its ability, reliability and flexibility in analyzing BMSSs.

I present a brief description of the method, its main scheme and equations. And the analysis of the system Hip 111170 as an example for the use of the method.

The method employs Kurucz ATLAS9 line-blanketed plane-parallel model atmospheres to build the synthetic spectral energy distributions (SEDs) for the unresolved individual components. From which it builds SED of the entire system, which can be used to calculate synthetic photometry comparable to the observational ones as strict reference points. The availability of the observational SED would be an additional reference point.

The method is suitable for all kinds of BMSSs. It gives a precise dynamical parallax for any system given that it has a good orbital solution, either outer or inner, visual or spectroscopic orbits. The analysis of the system Hip111170 showed that system consists of two main-sequence solar-metalicity of 2.239 Gyr stars, formed by fragmentation.

KEYWORDS Stars: binaries, Model Atmospheres, Synthetic Spectra, Multiple Stellar Systems, Synthetic Photometry, Al-Wardat's Method, Stellar Masses

Stellar parameters of the close binary system: HIP 27758

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We present the best stellar parameters of the close binary system (HIP 27758) for the first time using Al-Wardat's method for analyzing binary and multiple stellar systems. The method combines the results of the spectroscopic analysis with the photometric analysis and then compares them with the observed ones to construct the best synthetic spectral energy distributions (SEDs) of the system. The method implements Kurucz's plane parallel model atmospheres. The analysis gives the precise astrophysical parameters of the individual components of the system. Based on the positions of the components of HIP 27758 on the H-R diagram, we found that the system belongs to the main sequence stars with mass of 1.24 and 0.98 solar masses and age of 2.239 Gyr. Finally, the positions of the individual components of the system are given on the evolutionary tracks and isochrones, and its formation process is discussed.

KEYWORDS stellar parameters, close binary system, synthetic stellar photometry, HIP 27758

FM 9
#1576

A grid of subdwarf's synthetic spectra to study hot stellar components in old stellar populations

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The integrated properties of old stellar populations contain evolved and hot stellar components which are often neglected in population synthesis models, thus hampering our ability to measure ages. In this work, we present a new grid of detailed atmosphere models and synthetic spectra for hot-high gravity subdwarf stars (Pacheco et al. 2021, ApJS, 256:41). High-resolution spectra and synthetic photometry are calculated in the range from 1000 A to 10,000 A using Non-LTE fully line-blanketed atmosphere structures. Our grid covers eight temperatures within 10,000 ≤ T eff [K] ≤ 65,000, three surface gravities in the range 4.5 ≤ log g [cgs] ≤ 6.5, two helium abundances matching an extreme helium-rich and helium-poor scenarios for subdwarfs, and two metallicities representatives of the solar neighborhood ([Fe/H] = 0) and Galactic halo ([Fe/H] = -1.5 and [α/Fe] = +0.4). Besides its application to determine subdwarfs' fundamental parameters in isolation and binaries, the resulting database is also of interest for population synthesis procedures in a wide variety of stellar systems. Our grid is applied, in addition to a published library (Coelho 2014, MNRAS, 440, 1027–1043), to the study of simple stellar populations (SSP) with extended horizontal branch morphologies, using the color-magnitude diagram of NGC2808 as a proxy (Pacheco et al. in prep). With these models, we are able to estimate the implication of hot stellar components on the integrated spectrum of galactic globular clusters, ultimately increasing the accuracy of age determinations from the integrated light spectrum.

KEYWORDS Stellar populations, Stellar atmospheres, Spectral energy distribution, Stellar spectral lines, Subdwarfs

FM 9

#1236

X-rays in stellar atmospheres: The case of cool B supergiants

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After a few million years, massive stars quickly evolve off the main sequence into a regime where we find so-called B supergiants (BSGs). In this region of the Hertzsprung–Russell diagram, we find stars of different evolutionary origins, raising fundamental questions about the role of BSGs: Are they hydrogen- or helium-burning objects? Are they evolving redwards or bluewards? Are they, as typically assumed, direct descendants of main-sequence stars or are they actually post-red supergiant objects?

To correctly identify the role(s) BSGs occupy in the evolution of massive stars, it is essential to analyse the spectra of these objects and identify their stellar and atmospheric parameters. In this work, we focus on the so far rarely studied cooler BSGs - i.e. with spectral types later than B1, corresponding to temperatures below the so-called Bi-Stability Jump region. Using CMFGEN and PoWR, we performed a quantitive analysis including the effects of clumping and shock-heated X-rays in the wind. By including these physical ingredients in our models, we were able to reproduce the combined UV and optical spectra of our sample stars, overcoming previous difficulties reported in the literature to explain important UV profiles of higher ionization stages.

Our results show that both X-rays and clumping need to be taken into account for cooler BSGs, but their properties are quite different to those in hotter BSGs. For our targets, we derive Lx/Lbol ratios considerably lower than the typical 10-7. This in line with the observed X-rays for such objects, but also demonstrate that X-rays as such cannot be neglected in cooler BSGs. Concerning clumping, our obtained parameters reveal that cooler BSGs have significantly smoother winds than hotter BSGs, confirming recent hydrodynamical predictions. We discuss the consequences of our investigation for B supergiants in the context of atmosphere modeling across the Bi-Stability Jump in hot massive stars and implications for stellar populations.

KEYWORDS massive stars, B stars, B supergiants, stellar wind, X-rays, wind clumping, stellar feedback

FM 9
#1292

The Challenges of Modelling Wolf-Rayet Atmospheres: Prescribed and dynamically-consistent Winds

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Hot, massive stars are strong contributors of chemical enrichment, ionisation and mechanical energy, thereby leaving a strong imprint on their host galaxies. A subset of the hot and massive stars with a particularly high impact are Wolf-Rayet (WR) stars, showing emission-line dominated spectra originating in their strong stellar winds. WR emission lines are so strong, that they leave so-called bumps in the integrated spectra of star clusters and galaxies, proving the presence and influence of WRs therein.

Despite their huge impact, the modelling of WR star atmospheres remains an ongoing challenge. The inherent non-LTE environment and the optically thick wind demand a detailed and costly numerical treatment. Consequently, the hydrodynamic structure of the wind has traditionally been approximated by prescribed velocity laws, typically the so-called beta-velocity law. Unfortunately, this approximation seems to be insufficient as several discrepancies have piled up during the application of traditional WR atmospheres over time, most notably a large difference between radii inferred from observations and from stellar evolution modelling.

In our study, we quantify this problem by computing and analysing non-LTE WR atmospheres, adopting several different wind velocity fields for typical stellar parameters. Our results demonstrate that the different velocity fields have a profound impact on the spectral appearance of the star, strongly impacting emission line features typically used as spectral diagnostics. To overcome these discrepancies, we turn to improved velocity descriptions obtained by consistently solving the hydrodynamic equation of motion. In this talk, we will outline the principles of WR atmosphere modelling, present the spectral imprint of our study using different assumptions for pre-described velocity fields, and eventually discuss the first results of our hydrodynamically-consistent atmosphere models introducing a new generation of WR-star atmospheres.

KEYWORDS stars: atmospheres, stars: Wolf-Rayet, stars: winds

FM 9

#1794

Current status and future prospects of the STAGGER grid

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3D stellar atmosphere models have been and still are widely used in different fields in astrophysics, which has allowed astronomers to study stellar granulation, stellar abundances, limb darkening, among other phenomena. Some of these studies have been possible thanks to the STAGGER grid, a grid of more than 200 3D stellar atmosphere models distributed across the HR diagram. Even though the grid has been used for several applications successfully, it does require several updates, so that current and future projects, such as the PLATO mission, can use it. In this talk, I will present the current status and the future plans of the STAGGER grid, which entails the improvement of original models, and the refinement of the grid. Additionally, I will briefly talk about the challenges that we need to face for future developments of 3D models.

KEYWORDS stars: atmospheres, convection, hydrodynamics, Astrophysics - Solar and Stellar Astrophysics, methods: numerical

FM 9

#2873

3D hydrodynamical model atmospheres of M-dwarfs

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In recent years M-dwarfs started gaining attention as the most abundant stars in the universe coupled with highest likelihood to find planets around them. However, just as these stars were rarely studied in spectroscopy due to their faintness and complex spectra, they were left out from modern 3D model atmosphere grids as well. In this report we present the first results of our systematic study of M-type dwarf atmospheres with the aid of 3D hydrodynamical CO5BOLD model atmospheres. For this, we computed an extensive 3D model grid covering effective temperatures from 4000 K to 3000 K and surface gravities from log g = 4.5 to 5.0. Our analysis shows that while the effects of convection are generally relatively mild in the atmospheres of M-type dwarfs, they may nevertheless lead to noticeable changes in their observable properties, such as the spectral line strengths and photometric colors: the 3D-1D differences in abundance corrections may reach to ~0.15 dex and photometric color indices to ~0.2 mag in the extreme cases. We discuss the implications of these findings for the future analysis of M-type dwarfs, in particular in the context of forthcoming ground- and space-based photometric and spectroscopic surveys.

KEYWORDS convection, hydrodynamics, radiative transfer, stars: atmospheres, stars: late-type

FM 9

#2007

3D model atmospheres and line formation calculations with non-standard chemical compositions

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We have entered an era where the advance of astronomy is driven by large surveys. The release of Gaia DR3 and the continuing development of large spectroscopic surveys such as APOGEE, GALAH, WEAVE, and 4MOST will provide new insights into the physics of stars and planets, and the formation and evolution of our Galaxy. With numerous precise observational data available, it is crucial to push the frontline of theoretical stellar model atmospheres and model spectra. We shall describe our recent developments to the Stagger 3D MHD stellar atmosphere code, not least of which include a new implementation of the equation of state and opacities that allow for more flexibility to compute models with arbitrary chemical compositions as well as better consistency with the 3D non-LTE spectrum synthesis. We also showcase how the atmosphere stratification will change when modifying the abundance of α-elements. These improvements open a new window for studying stars with different α-element abundance, carbon-enhanced metal-poor stars and population II and III stars with peculiar chemical compositions.

KEYWORDS equation of state, opacity, convection, hydrodynamics, stars: atmospheres, line: formation

FM 9

#496

Modelling the Milky Way's most metal-poor star

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Late-type ultra metal-poor stars are thought to be formed from interstellar gas enriched by only one to few supernovae. As such, their elemental abundances and total metal content are important in understanding the limits of star formation in the early universe and the chemical evolution of the Milky Way. In this talk, I will present an updated chemical abundance analysis of the most metal-poor star known to date (SDSS J102915+172927) using new stellar parameters from Gaia DR2 and a tailored 3D atmospheric model, first discussed by Caffau et al. (2011). This work showcases the advantages of state-of-the-art 3D atmospheric models and 3D NLTE radiative transfer compared to commonly used 1D LTE methods. In addition, we are revitalising and expanding the STAGGERgrid of 3D stellar models together with collaborators from Aarhus university. This is especially interesting in the prospect of upcoming large spectroscopic observing campaigns like GALAH, WEAVE, and 4MOST, which will release a wealth of spectroscopic data, including hundreds of thousands of metal-poor stars.

KEYWORDS Metal-poor stars, Spectroscopy

Improving planetary atmosphere characterization by 3D NLTE modeling of the stellar centre-to-limb effect

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The center-to-limb variation (CLV) of the stellar lines across the stellar disk is an important effect for planetary transit spectroscopy. Indeed the variation of spectral line profiles when the planet transits different part of the stellar disk can affect the determination of elemental abundances in the planetary atmospheres, as shown by Yan et al. (2017).

Accurately modelling the CLV effect of planet-host stars is fundamental to better characterize the planetary transmission spectrum and to correctly detect and measure abundances of atmospheric species.

However, we know that the commonly used 1D plane-parallel LTE atmosphere models fail to reproduce spatially resolved observations of the solar disk. 3D hydrodynamic models and non-LTE line formation is required for an accurate modelling of the CLV effect.

So far, the best studied atomic lines in transit spectroscopy are the Na D lines and the NIR K resonance lines. In this talk I will present new results regarding the modelling of these lines in the Sun using 3D NLTE radiative transfer and discuss possible implications for transit spectroscopy.

KEYWORDS Transit spectroscopy, stellar atmosphere, radiative transfer, center-to-limb variation

FM 9

#349

Grids of 3D NLTE spectra in practice

Xi Wang[1]

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3D NLTE spectral synthesis produces the most physically realistic spectra available. However, there are still issues present in modelling and applying these calculations to observations. On the modelling side, I will present 3D NLTE calculations of Fe on a high resolution model atmosphere, which show some surprising issues. On the application side, 3D NLTE spectral synthesis are computationally expensive and thus only sparse grids can be computed. The interpolation of sparse grids can be inaccurate using traditional interpolation methods such as spline interpolation. I will present a possible solution based on machine learning methods.

KEYWORDS line: profiles, radiative transfer, techniques: spectroscopic, stars: abundances, stars: atmospheres, stars: latetype

FM 9

#2400

Non-LTE impact of Ti I and Ti II on metal poor type star abundances

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With a high number of spectral lines, titanium is a fantastic metal to use for determining atmosphere parameters such as surface gravity, alpha enhancement, and effective temperature. To do so, accurate departure coefficients from local thermodynamic equilibrium (LTE) must be known. Common LTE assumptions have proven dangerous when estimating Ti I and Ti II level populations in late-type stars. A substantial ionisation imbalance is revealed when departing from LTE into Non-LTE (NLTE). With Ti I being a minority in stars, its perturbation is easier and low excitation level predictions lead to a lower estimation of abundance than when using Ti II, especially for hot and metal poor stars. If Ti I predictions can be brought in line with Ti II, it would greatly improve the abundance accuracy and help better seperate stellar populations in the disk and halo. Previous works have made fantastic progress in estimating NLTE effects for titanium. Now with new accurate quantum mechanical data for hydrogen collisions and photoionization, we have made a larger and more detailed atomic model. Combining this with the powerful 3D radiative transfer code BALDER, we analyse the ionization imbalance in 5 benchmark stars in 1D and 3D NLTE.

KEYWORDS NLTE, Titanium, Abundance, Spectra, Metal-poor, Dwarfs, Red-Giants

FM 9

#2350

A library of high-resolution spectra of 3D model atmospheres

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3D model atmospheres of late-type stars provide the full information on the thermal structure and flow kinematics of the stellar surface layers. This can be exploited for calculating synthetic spectra exhibiting features like spectral line shifts and line asymmetries. We report on a project calculating synthetic spectra for a sample of 3D model atmospheres. The spectra are computed under the assumption of LTE. They have a high spectral resolution, and cover a wavelength range from the near-UV to the K-band. Besides computational challenges, we point to already existing and potential future applications of such spectra.

KEYWORDS 3D models, synthetic spectra, late-type stars, hydrodynamics

FM 9
#1281

Accurate iron abundances of dwarf stars

Anish Amarsi[1]

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Iron is one of the most important elements in stellar astronomy: by virtue of its large cosmic abundance and rich electronic structure, it is the usual proxy for overall stellar metallicity, and a convenient tracer for the chemical evolution of our Galaxy. However, classical iron abundance determinations, characterised by one dimensional (1D) hydrostatic model atmospheres and/or the assumption of local thermodynamic equilibrium (LTE), are prone to systematic errors. This is particularly concerning for spectroscopic surveys which use excitation and ionisation balance of FeI and FeII lines to inform other stellar parameters and elemental abundances. I shall present recent 3D non-LTE radiative transfer calculations for iron in dwarf stars spanning a range of metallicities, and discuss the errors associated with the 1D LTE and 1D non-LTE assumptions.

KEYWORDS atomic processes, radiative transfer, line: formation, Stars: atmospheres, Stars: fundamental parameters, Stars: abundances

FM 9
#790

3D abundance analysis of the most iron-poor stars

Thomas Nordlander[1]

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The most iron-poor stars are thought to be direct descendants of the first stars in the Universe. Their abundances of carbon and oxygen are uniquely sensitive tracers of the supernova mechanism and properties of the progenitor star, and hence offer a window to explore these long dead stars.

However, abundance measurements of carbon and oxygen are challenging as they rely on measuring molecular bands whose line formation is complex. I will present a large grid of calculations on the molecular line formation for extremely iron-poor stars, based on 3D hydrodynamic model atmospheres. I will also discuss the chemical composition of some of the most primitive stars in our Galaxy, and implications for the first stars.

KEYWORDS Stars: abundances, Stars: Population II, Stars: Population III, Radiative transfer

FM 9
#2638

Speeding up 3D non-LTE spectral synthesis with neural networks

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Three-dimensional non-LTE calculations are the gold standard for spectral synthesis in stellar atmospheres. However, such calculations require tremendous amounts of computer time, on the order of a million times more than the 3D atmospheric simulations, which are already time-consuming. We present results from a new approach to compute 3D non-LTE spectra using neural networks. We make use of 3D rMHD simulations of the solar atmosphere to synthesise Hα spectra, which are strongly affected by 3D. Using a database of previous calculations, our code - SunnyNet - learns the translation from LTE to non-LTE atomic populations, which we then use to predict the non-LTE populations for a different atmosphere, and compute synthetic spectra. This approach leads to a speedup of 105 times compared to existing codes, when running on a single GPU. The quality of the predicted populations is best when using different timesteps of the same simulation for training and testing: usually about 20-40% of the true values for most points in the atmosphere. This translates to typical differences of less than 4% in the Hα spatially-averaged intensity spectra. Synthetic images at the Hα line core reproduce chromospheric fibrils very well, strongly suggesting that SunnyNet is learning 3D radiative transfer, since fibrils are absent in 1D calculations. While our results are oriented towards high spatial resolution and the dynamics of the solar chromosphere, there is much that can be applied to spectral synthesis of other stars. We will discuss the current limitations and caveats, and suggest possible improvements and modifications to make our approach work for abundance studies, including adding many more spectral lines and atmospheric models of different stars.

KEYWORDS Line: formation, Radiative transfer, Stars: atmospheres

FM 9
#993

Fiorella Castelli and her legacy

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Fiorella Castelli devoted most of her scientific career to the modelisation of stellar atmospheres and the study of stellar spectra, with a special focus on stellar abundances. Early on she began to develop her own spectrosynthesis code SYNTH. After arriving at the Astronomical Observatory of Trieste in the 1970's she began a vigorous scientific activity in stellar spectroscopy both in the visible and in the UV spectral ranges computing ``ad hoc'' model atmospheres.

She became one of the early users of the ATLAS model-atmosphere code, written and developed by R.L. Kurucz, and began to collaborate with him debugging the code and contributing to its developement. She was always ready to share her knowledge with others and was a key figure in the evolution of the field that from the mid-1980s to the mid-1990s transformed the use model atmospheres and synthetic spectra from a niche, reserved to a few initiated, to a main stream research topic and widespread tool for the analysis of stellar spectra.

Sadly Fiorella left us on July 26th 2019. In this contribution we shall try to summarise some of her main contributions to the field, from the analysis of high resolution spectra to that of stellar spectral energy distributions, from the computaton of mode atmospheres to that of theoretical colours.

Although some of us have directly benefited directly from Fiorella's collaboration and guidance, many more have benefited from models, codes and data that she shared through her web site.

KEYWORDS stars: atmospheres, stars: spectra, stars: abundances, stars: photometry

FM 9

#3446

The Milky Way in Context: Building an IFS Datacube of the Galaxy

Zixian Wang[1], Michael Hayden[1], Sanjib Sharma[1], Jesse van de Sande[1], Joss Bland-Hawthorn[1]

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Our Milky Way is by far the best studied galaxy in the Universe, and it has long been regarded as a benchmark for understanding disk galaxies. However, the Milky Way is only one galaxy, and it is crucial to link the galactic and extragalactic research to understand the formation and evolution of disk galaxies. Currently, one challenge is that the galactic and extragalactic observations are not in the same data format. In this work, we present a novel approach to generating the mock IFS data cube of the Milky Way by making use of the SSP spectral libraries and E-Galaxia. This tool can be used to compare the Milky Way with external disk galaxies directly, to look for signatures of formation processes in the detailed chemo-dynamical structure of disks, such as their velocity dispersion profiles, the radial and vertical age gradients and the mass fraction of the [α/Fe]-rich versus [α/Fe]-poor populations.

KEYWORDS

FM 9

#3291

Analysing Binary stellar system (HIP 101181) Using Al-wardat method

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In this study, we analyzed a binary stellar system using Al-Wardats method for analyzing binary and multiple stellar systems to present the atmospheric and fundamental parameters and the masses for the individual components of the binary stellar system (Hip101181). Al-Wardats method benefits from ATLAS9 model atmospheres to compute a synthetic spectral energy distribution (SED) for each component separately and the entire (combined) system. Using the estimated parameters, the positions of the components were located on the evolution track in the Hertzsprung–Russell (H-R) diagram with an age of 2.239 Gyr. The system components evolved to the giant region with mass greater than solar mass, component A 1.41$M_{\odot}$ while component B 1.2$M_{\odot}$. The difference between the estimated masses and the dynamical ones leads to new dynamical parallaxes for the system: (8.78327 ± 0.45) mas.

KEYWORDS

FM 9

#3271

Follow-up of stars enriched in neutron-capture elements identified in the GALAH survey

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Old, metal-poor stars offer valuable information for the understanding of the formation and evolution of our Galaxy. Because the material that formed these stars has been enriched by only one or maybe few nucleosynthetic sources, the study of their chemical composition may give unique insight into the early history of Galactic chemical enrichment. Interestingly, a fraction of these old stars has been found to be enriched in r-process elements. The r-process is a neutron capture nucleosynthetic mechanism that produces the heaviest elements in the periodic table, alongside the s-process. The astrophysical sources of the r-process elements are, however, still a mystery. Neutron star mergers (NSM) have recently been confirmed as one such source, but the long timescale for their coalescence suggests that NSM cannot be the only r-process site. The current era of large stellar surveys, like Gaia, APOGEE, and GALAH, offer the chance for the identification and study of larger samples of metal-poor stars. This is thus a unique chance to obtain a holistic view on all the possible sources of the r-process. In this work, we report preliminary results of an observational campaign to follow-up chemically peculiar metal-poor stars identified from the catalogue of large surveys. For the target selection, we cross-matched GALAH sources with the Gaia EDR3 catalog. We selected stars with [Fe/H] ≤ -2 and relative [Ba/Fe] and [Eu/Fe] abundances that deviate by more than three standard deviations from the mean of the sample. This selected 34 candidates for the follow up. As a pilot study, we obtained data for two stars (TYC 9219-2422 and BPS CS 29529-0089) with the UVES spectrograph of the VLT in period 108. We obtained blue (centered at 390 nm) and red (at 580 nm) spectra which allow us to investigate abundances of several heavy elements (e.g., Eu and Ba) using spectrum synthesis. We present the atmospheric parameters (effective temperature using the infrared flux method of Casagrande et al. 2021; surface gravity using Gaia parallaxes; and metallicity using Fe II lines as in Smiljanic et al. 2021) and chemical abundances derived using spectrum synthesis. We also analyze the orbits and dynamic properties of these stars to understand if they were formed in-situ in the Galactic halo or were accreted from external galaxies.

KEYWORDS metal-poor stars, UV spectroscopy, spectroscopic surveys, chemical abundances, Gaia, GALAH

FM 9

#1251

Career and Accomplishments of Fiorella Castelli

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Fiorella Castelli dedicated her scientific life to stellar spectroscopy.
Her work together with R. L. Kurucz on ATLAS9 model atmospheres is well-known and widely used by astronomers all over the world. Fiorella's synthetic spectral libraries for multiwavelength observations, from the UV to the near-infrared, for different types of stars and at different evolutionary stages are famous and indispensable in studies of stellar chemical abundances. Furthermore, her contributions to the atomic database including wavelengths, energy levels and loggf values for different elements, both in UV and optical regions, greatly contribute to computing stellar synthetic spectra. Fiorella also pioneered the work on various isotopic anomalies discovered in the spectra of different types of stars. She also has widely shared her work, including high-quality high-resolution spectra of template stars, trying to label all spectral lines, publicly available from her website. It was an honor and pleasure for all of us to work with Fiorella on nearly a score of publications over more than 25 years.
In this poster, we discuss Fiorella's pioneering contributions on various aspects of stellar spectroscopy.

KEYWORDS spectra, stars, synthesis, models

FM 9

#1265

Galactic chemical evolution, solar twins, and a toy model for the engulfment of earthlike material

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Galactic chemical evolution (GCE), solar analogues or twins, and peculiarities of the solar composition with respect to the twins are inextricably related. We examine GCE parameters from the literature and present newly derived values using a quadratic fit that gives zero for a Solar age (i.e., 4.6 Gyr). We show how the GCE parameters may be used not only to ``correct'' abundances to the solar age, but to predict average relative elemental abundances as a function of age. We address the question of whether the solar abundances are depleted in refractories and enhanced in volatiles and find that the answer is sensitive to the selection of a representative standard. The best quality data sets do not support the notion that the Sun is depleted in refractories or enhanced in volatiles. A simple model allows us to estimate the amount of refractory-rich material missing from the Sun or alternately added to the average solar twin. The model gives between zero and 1.4 earth masses.

KEYWORDS stars, abundances, spectra

FM 9
#2954

Space distributions and the HR Diagram of Cataclysmic Variables from Gaia Data

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In this study, the trigonometric parallaxes of the Gaia EDR3 catalog are used for systems known as cataclysmic variables (CVs) in the literature. The spatial distributions of CVs in the heliocentric Galactic coordinate system were obtained and their positions in the Hertzsprung-Russell (HR) diagram created from Gaia colors were discussed. Scale height for CVs were derived from Gaia's sensitive astrometric data.

KEYWORDS Gaia, Cataclysmic Variables

FM 9

#864

Spectroscopic study of the RV Tauri star R Scuti

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To study the correlation existed between H emission lines and shock waves for the RV Tauri variable R Sct, a bright RV Tauri star well known for its very irregular light curve with variable amplitude and pulsation period, we used the spectroscopic data distributed over two cycles during 2016, where the R Sct star shows a small variation in-depth and shape of its light curve (39 spectra distributed over 200 days, 25 spectra from Oukaimeden Observatory and 14 spectra from the Narval database). During the pulsating motion, the atmospheric gas accelerates and decelerates. As a result, shock waves can be created. However, the existence of emission lines can, generally, indicates the propagation of a shock wave through the atmosphere. We found that the Balmer H line shows considerable changes in the optical spectrum of R Sct with the light variability. Double-peaked emission and an inverse P Cygni profile are observed in this line. These features appear at phases around = 0.2 (0.19-0.32) and = 0.7 (0.67-0.83) in several cycles, which is consistent with the passage of two shocks waves through the stellar photosphere, around = 0.2 (just after the deep minimum) and = 0.7 (just after the shallow minimum). Also a decrease in the intensity of H is observed when the shock wave speed goes from 82 Km/s to 120 km/s, which can be explained by the ionization phenomenon.

KEYWORDS stars, variable, atmosphere, atmosphere, shock wave, profile, R Sct

e-Talks

FM 9

#2634

Atmospheric parameters of individual components of the visual Triple Stellar system HIP 32475

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We present a complete analysis for the individual components of the ABC visual triple system HIP 32475. AB pair was discovered during the Hipparcos mission, with a separation of 412 mas. Later, in 2015, a third component added to the system by discovering it at a small angular distance from B.

There are three different proposed solutions for the orbit of AB, which give different mass sums and different estimations for the evolutionary stages. So, there is a need for another way of analysis to reveal the nature of the system.

In our analysis, we follow AL-Wardat's method for analyzing binary and multiple stellar systems, which is a computational spectrophotometric method. . It employs Kurucz ATLAS9 line-blanketed plane-parallel model atmosphere to build the spectral energy distributions of the individual components. Using estimated parameters, the components' position on the H-R diagram, evolutionary tracks, and isochrons are defined. From which we estimate the age of the system as 1.259 Gyr with a metallicity of $Z=0.019$. The results show that component A started to evolve from the main sequence to the subgiants stage, while components B and C are still in the main sequence stage.

KEYWORDS Visual, Stellar formation, Stellar evolution, synthetic spectra, Synthetic photometry, Parallax, isochrones

FM 9

#506

Bridging the Gap between Theory and Data by Leveraging Large Data sets

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Various spectroscopic surveys are providing an immense number of spectra from which we can study stellar properties and elemental abundances of stars. Modern automated approaches for analyzing spectra are either (a) based on data-driven models, which require an extensive grid of empirical spectra with prior knowledge of their stellar labels, or are (b) based on theoretical synthetic models that are susceptible to model systematics. In this talk, I will present a hybrid generative domain adaptation method, Cycle-StarNet, which overcomes these limitations. Cycle-StarNet generates systematics corrected spectral models and establishes data-driven models without the need for a labelled training set. Moreover, Moreover, Cycle-StarNet can also identify element-specific missing spectral features in the models. Cycle-StarNet provides a new methodology to auto-calibrate models, in stellar spectroscopy and beyond, capitalizing on large data sets from spectroscopic surveys and the latest technologies in machine learning.

KEYWORDS Spectroscopy, Machine Learning

FM 9

#2932

Stellar population models with varying abundances to determine the formation time scales of small and big galaxies

Iveth Adaena Gaspar Gorostieta[1], Alexandre Vazdekis Vazdekis[1], Carlos Allende Prieto[1]

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We have computed a theoretical library of stellar spectra, from Near-UV to Near-IR (from ~0.3 to 2.3 micron), with varying abundance element ratios. We built-up a new set of semi-empirical stellar spectral libraries that incorporate these abundance variations. This is performed by adapting these theoretical libraries to the instrumental set-up of the newly observed XSL library, obtained with the X-Shooter at the VLT. Then we derive abundance-dependent spectral responses, which are applied to the real stars to create semi-empirical versions of the XSL library with varying abundances. The new semi-empirical XSL libraries include reliable differential corrections for cool stars, which are particularly relevant in the NIR range of galaxy spectra. The moderately high resolution (~10000), wide spectral range and great atmospheric parameters coverage of the XSL, endowed with varying abundance ratios makes the resulting set of semi-empirical XSL libraries ideal to compute stellar population models to interpret a rather wide variety of galaxy spectra.

KEYWORDS techniques: spectroscopic, stars: abundances, stars: atmospheres

FM 10

Synergy of Small Telescopes, and Large Surveys for Solar System & Exoplanetary Bodies Research

Invited & Contributed Talks

FM 10

#616

ExoMiner:
A Highly Effective Deep Learning Classifier to Mine Exoplanets

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ExoMiner is a new deep neural network we have recently developed and used to validate hundreds of new exoplanets from the Kepler mission. ExoMiner utilizes most unique elements of Kepler SOC/TESS SPOC data validation summary report in their original format in order to classify transit signals. This is unlike the existing machine classifiers that either do not use a comprehensive list of diagnostic tests required for the correct classification or use a simplified version of these tests in the form of a few scalar values. In this talk, we will present ExoMiner, its unique characteristics, and what makes it highly accurate and suitable for exoplanet validation. We also introduce ExoMiner++, a more powerful version of ExoMiner, that addresses the existing shortcomings of the ExoMiner and is more suitable to handle TESS data. When trained on Kepler data, ExoMiner++ is able to accurately classify TESS signals with little fine-tuning. We will also introduce a new explainability framework that provides explanation on ExoMiner++ disposition in domain language form such as "This signal is an eclipsing binary because of odd and even transit depth difference.".

KEYWORDS machine learning, Kepler, TESS, exoplanet, transit photometry, deep learning, deep neural network

FM 10
#738

Enhancing and Optimizing TESS's Scientific Output using Machine Learning

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NASA's Transiting Exoplanet Survey Satellite (TESS) mission shows the power of small telescopes in today's big-data era. Every month, TESS observes millions of stars with its four 10 cm aperture telescope and relays the data to the ground, where it is analyzed and searched for planets. So far, TESS has discovered over 5000 planet candidates that are currently being scrutinized by a bevy of ground-based telescopes to identify and rule out false positives. However, the sheer size of TESS's dataset necessitates new methods to more efficiently identify and follow-up new planet discoveries. We are using advanced machine learning methods, in particular deep learning, to accelerate TESS's scientific discoveries both by automatically identifying planet candidates and enhancing the sensitivity of follow-up observations. Our deep convolutional neural network classifier, Astronet, is trained to determine whether any given signal detected in transiting exoplanet surveys like Kepler or TESS is due to a real planet or is some type of false positive. Our most recent version of Astronet is currently being used in the TESS Quick Look Pipeline, one of the methods used to produce the official TESS planet candidate catalog. Meanwhile, we are exploring whether deep learning can increase the sensitivity of radial velocity observations to smaller planets. Currently, radial velocity observations to confirm TESS planet candidates are often limited by astrophysical noise from stellar magnetic activity. We have prototyped a machine learning solution by training neural networks to recognize and remove this noise signal. Our initial tests show promise for increasing the sensitivity of these observations. Deep learning methods like these will help astronomical discovery with TESS keep pace with our growing datasets.

KEYWORDS TESS, exoplanet, machine learning, transit, radial velocity

FM 10

#1082

MINERVA-Australis: A Southern TESS follow-up machine

Rob Wittenmyer[1]

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NASA's Transiting Exoplanet Survey Satellite (TESS) has identified more than 5000 planet candidates in its first three years of operation.

Spectroscopic follow-up of these planets remains a bottleneck, with more than 95% of candidates awaiting confirmation. MINERVA-Australis is a partnership between MIT, UNSW Sydney, George Mason University, University of Louisville, Nanjing University, UC-Riverside, University of Texas, and the University of Florida. It is the only southern hemisphere observatory wholly dedicated to the detailed follow-up of TESS planets, and has contributed to the confirmation of 30 planets to date -- about 15% of all TESS confirmed planets. I present mass measurements and system parameters for several new planets using MINERVA-Australis radial velocities, and give preliminary results from our new multi-telescope photometric capability to validate small TESS planet candidates. I also describe our longer-term plans for extended mission science, taking advantage of the unique capabilities of this dedicated observatory.

KEYWORDS TESS, Exoplanets, radial velocities, photometry, 1m-class telescopes

FM 10

#2533

SPECULOOS: Hunting exoplanets of ultracool dwarfs with 1-meter ground-based telescopes network

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The SPECULOOS (Search for habitable Planets EClipsing ULtra-cOOl Stars) project aims to perform a transit search on the nearest (< 40 pc) ultracool (<3000K) dwarf stars. The project is based on a network of 1m robotic telescopes, composed by the four ones of the SPECULOOS-Southern Observatory (SSO) in Cerro Paranal, Chile, one telescope of the SPECULOOS-Northern Observatory (SNO) in Tenerife, and the SAINTEx telescope in San Pedro Martir, Mexico. The prototype survey of the SPECULOOS project on the 60 cm TRAPPIST telescope (Chile) discovered the TRAPPIST-1 system, composed of seven temperate Earth-sized planets orbiting a nearby (12 pc) Jupiter-sized star. The project's main motivation is to discover potentially habitable planets well-suited for detailed atmospheric characterisation with upcoming giant telescopes, like the James Webb Space Telescope (JWST) and European Large Telescope (ELT).

The SPECULOOS target list contains a homogeneous selected sample of close-by low-mass and ultracool stars. The targets have been selected as low-mass dwarfs starting from the Gaia DR2 catalogue, which has been cross-matched with the 2MASS point-source catalogue. Beside conducting observations of targets from the SPECULOOS input catalog, a fraction of the available observing time of the SPECULOOS network is used to carry out different science goals, the so-called annex programmes. A large annex programme is the support of space based transit search surveys such as K2 and TESS through the follow-up of transit candidates of late-type dwarfs.The upcoming Gaia DR3 release will largely improve the parallaxes and colours for the 40 pc sample, thus encompassing more targets that were excluded in our original target list.

In these talks we are going to present our observation strategy, management of our archive and scientific products. We will discuss the first results of the survey and the synergy of our programs with the Transiting Exoplanet Survey Satellite (TESS), JWST and the future releases of the Gaia mission.

KEYWORDS exoplanets, planetary systems, catalogs, low-mass stars, surveys

Exoplanet Demographics: Exploring The Multiplicity of Planetary Systems

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As we continue to push the limits of exoplanet detection, we find again and again not only that exoplanets are common, but that multi-planet systems are common. Systems with a single planet may be the exception, not the rule. Here I will review what we have learned across multiple detection techniques exploring different planet parameter discovery space about the multiplicity and architecture of planetary systems - what we know and what we don't yet know. These results include the loneliness of hot Jupiters, the correlation between the occurrence of close-in super-Earths and more distant companions, the clustering of planet sizes and periods within systems, the counter-intuitive result that M dwarfs appear to be more efficient at creating close-in multi-planet rocky systems than their larger counterparts, and the fact that multiple detection biases across the various detection techniques confound our ability to detect and disentangle multi-planet systems. There are a number of ways that both small telescopes and large surveys can contribute to mitigating these biases and help us unlock the complete architecture of exoplanet systems.

KEYWORDS exoplanets, multiplicity, architectures, detection, demographics

FM 10

#827

Characterising the atmospheres of exoplanets using high-resolution transmission spectroscopy

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Since the discovery of the first exoplanet over 25years ago, enormous progress has been made. Not only do we now know of more than 5000 exoplanets, but we have also started to characterise their atmospheres. One of the main ways to perform such characterisation is using transmission spectroscopy. During a planet's transit, light from the star filters through the planet's atmosphere and gets imprinted with its signature. Such observations have not only revealed the presence of different species, thereby providing insight into the planet's composition, but also signs of atmospheric dynamics, including winds, and spatial variations in the composition. I will provide an overview of what we have learned from these transmission spectroscopy observations so far and how can expand upon this to get insights not only in the current conditions on these planets, but also the formation and evolution history of exoplanets.

KEYWORDS Exoplanets, Atmospheres, Spectroscopy

FM 10

#1386

Using Small Telescopes to Photometrically Determine the Masses of Tatooine Planets

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Circumbinary planets, often referred to as Tatooine planets, are fascinating exoplanets because of their rich dynamics, potential for habitability, and of course because of their two suns. Their eclipses and transits provide extremely precise determinations of the three bodies' positions and velocities, which in turn lead to exquisite accuracy in the radii: <1% uncertainty has been obtained. However, determining the planet's mass is much more difficult. The radial velocity method generally fails because the reflex velocity induced by the planet is very much smaller than the orbital velocity of the binary stars themselves. This is where small telescopes can play a vital role. The key to deterermining the planet's mass is to measure changes in the binary star's period, and this is done by measuring the times of the primary and secondary eclipses. Such observations are relatively easy to make since eclipses are much deeper than transits - often 20% or more deep. Remarkably, a timing uncertainty of 30 sec in a system with a 30-day orbital period yields a precision of 12 ppm. This high precision allows us to measure the tiny effect the planet has on the binary stars, and thus constrain the planet's mass. The eclipse timing variations (ETVs) have two components: a short oscillation at half the timescale of the planet's orbital period, and a long-term drift in on a timescale of years. The longer-timescale ETV reveals the apsidal precession of the binary stars' orbit and also constrains the planet's mass. Importantly, this long-term signal grows linearly with time. Thus archival data and follow-up observations, even if they are relatively low precision, can provide very strong constraints on the planet's mass, especially if they extend the temporal baseline of the ETVs by a decade - which they often do (e.g. KELT, WASP, ASAS-SN, etc.). Thus small telescopes play a crucial role in Tatooine science by providing the ETVs necessary to determine the planet's mass.

KEYWORDS exoplanet, circumbinary, eclipse

FM 10

#1811

Small telescopes and big projects

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Despite the race towards gigantism in observational astronomy, both terrestrial and spatial, small ground based telescopes continue to make interesting discoveries and produce scientific results of great interest in several fields of astronomy and astrophysics.

We quote here as an example, the fabulous success of the Oukaimeden Observatory located in the High Atlas mountains in Morocco. Equipped with small telescopes (the largest having a diameter of 60 cm), it has nevertheless proved its great efficiency, taking advantage of the exceptional quality of its location and the completely automated and remote operation of all its instruments. One of his greatest achievements to date remains his participation to the discovery of the famous TRAPPIST-1 explanatory system.

We propose to present in this contribution some of the most important scientific results produced by this observatory as well as the projects in which it's involved thanks to a rich and diversified international cooperation that it has been able to drain.

KEYWORDS

FM 10
#2223

Solar System Science opportunities with the Vera C. Rubin Observatory Legacy Survey of Space and Time

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In 2024 the Vera C. Rubin Observatory, an 8m class ground based facility currently under construction at Cerro Pachón, Chile, will start scanning the entire southern sky periodically for a duration of 10 years. This unparalleled campaign is called the Legacy Survey of Space and Time (LSST), and is expected to result in the discovery of millions of Solar System Objects (SSOs) while simultaneously advancing many other scientific objectives. In this contribution we will discuss how Rubin/LSST Solar System Processing works, how the resulting data can be accessed and what opportunities this entails for astronomers interested in Solar System science with Rubin data. We will also give a brief description of current activities of the Rubin Solar System Science Collaboration.

KEYWORDS LSST, Rubin Obervatory, Solar System, Survey, Solar System Science Collaboration

FM 10

#1322

The Gaia Follow Up Network: state of the art and future objectives

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The ESA Gaia mission has been surveying the sky since July 2014. The now four data releases have shown the amazing properties of this data, from the creation of a three dimensional map of the Milky Way, to incredibly accurate observations of known Solar System objects.

In addition to that, a specific task within the Gaia Data Processing and Analysis Consortium has been created for the daily processing of possible new discoveries. The idea behind the pipeline is that when it's not possible to match the observations to a known object, a so-called alert is triggered and the object appears on the web interface of the Gaia Follow-Up Network (FUN) for Solar System Objects (https://gaiafunsso.imcce.fr/), making then possible to follow up the alert from the ground.

The Gaia asteroid alerts present some interesting challenges mostly because they have very short arcs, which means that the orbitdetermination is a complicated task. Nevertheless, at present, a few thousands of alerts were published,leading to successful recoveries of hundreds of objects (Carry et al. 2021, A&A).

I will present the state of the art of the pipeline, how the observations are submitted to the Minor Planet Center and the main results obtained from the follow up network. I will also talk about our expectations for the future of this pipeline, in particular about how we would still benefit from ground-based follow-up.

KEYWORDS Gaia, asteroid, alerts, solar system, astrometry

FM 10
#474

Recycling photons: The uses of archives in solar system searches

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Telescope archives have the potential to be incredibly useful for solar system astronomy. Archives allow astronomers to find precovery observations to refine the orbit of newly discovered objects. They also allow astronomers to obtain more data in different filters/wavelengths (to measure colours) or get a time series (to measure light curves). However, most archives do not provide a tool to search for images of moving objects. The Solar System Object Image Search (SSOIS) at the Canadian Astronomy Data Centre provides such a tool. SSOIS allows users to search for images of moving objects, allowing precoveries. SSOIS accepts as input either a list of observations, an object designation, a set of orbital elements, or a user-generated ephemeris for an object. It then searches for observations of that object over a range of dates. The user is then presented with a list of images containing that object from a variety of telescopes. Initially created to search the CFHT MegaCam archive, SSOIS has been extended to other telescopes including Gemini, Subaru, HST, the ESO and NOAO telescopes, Pan-STARRS and a growing number of other archives.

KEYWORDS solar system, archives, surveys

FM 10

#2704

Astrometric bias due to overlapping image profiles in the focal plane and its removal in the positions of near-Earth asteroids

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Both astrometric and photometric data of high accuracy provided by the Gaia catalog, its completeness to 21 mag allow evaluating the closeness of past astrometric positions of asteroids to the stars in the focal plane. In case the corresponding image profiles are overlapping, there is a photocenter bias shifting the positions measured towards each other. By correlating astrometric measurements of near-Earth asteroids collected at the IAU Minor Planet Center with the Gaia EDR3 catalog we identified 460,149 asteroid positions as of November 15, 2021, that had been measured within 9'' to stellar images, and thus, are likely affected by the photocenter bias to a varying degree. Assuming image FWHM constant for each observatory all year round, we have fitted the differences (O−C) in astrometric measurements of near-Earth asteroids. After doing that we recalculated the bias values and demonstrate the corresponding statistics. The identified measurements can be further rejected or down-weighted in the orbital fitting process for improving the overall orbital propagation. We emphasize the need of supplying the image FWHM each time the astronomers are submitting their astrometric measurements to the IAU Minor Plane Center.

KEYWORDS Near-Earth asteroids, asteroids, photocenter bias, ephemerides, orbital fitting

Astronomy for All
Busan 2022

FM 10

#1228

Searching Solar System and Exoplanetary Bodies the Data Science Way

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A sky survey covers a large part of the sky with a few outlined objectives, but also enables a greater variety of science if multiple filers are used or the cadence lends itself to varied time scales. Thus, the Zwicky Transient Survey - besides its outstanding work on Galactic and extra-galactic science - is enabling a large number of discoveries in the Solar System - from asteroids of various populations including near Earth ones, to comets. We will describe the machine learning methods that have enabled this. We will then describe how similar methods used with the TESS survey are leading to the discovery of exoplanet candidates that traditional methods may miss. We will finish with some future possibilities including interpretability and explaianability required when such machine learning methods are applied.

KEYWORDS asteroids, comets, exoplanets, machine learning, deep learning, data science, surveys

FM 10

#1710

NAROO: a New Astrometric Reduction of Old Observations

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During about one century, small telescopes participated to the astronomical observations through the use of photographic plates. The reduction of these data was made using old star catalogues with a poor accuracy. The arrival of the Gaia reference star catalogue makes possible performing a new reduction of these old observations allowing to "observe in the past" with today accuracy. We will present the status of this project.

KEYWORDS astrometry, photographic plates, solar system, transient events

Astronomy for All
Busan 2022

FM 10

#1695

Precovery and risk assessment of the hazardous Near-Earth Objects in large astronomical surveys

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For the first time in about four billion years, Earth's life has the capability to detect potentially destructive Near-Earth Objects and defend itself against their impact. Indeed this capability is being deployed and initiatives dedicated to the detection and surveillance of hazardous Near-Earth Objects (NEOs) have been initiated and coordinated by for example ESA's Planetary Defence Office. In this talk, I show how archival imaging data of wide-field astronomical surveys can be exploited to identify and re-assess the impact probability of these risky NEOs. As a pilot study, we performed a systematic search for the ESA risk-list NEOs appearances in archival observations of OmegaCAM. OmegaCAM is the wide-field imaging camera of the VLT Survey Telescope (VST), a 2 meters class telescope at ESO's Cerro Paranal Observatory and it is used for several wide-field surveys including the KiDS (Kilo-degree Survey) and VST-ATLAS surveys. While these surveys are not dedicated to the detection and surveillance of NEOs, we recover serendipitously several NEOs of the risk-list in this dataset. Interestingly, for a few cases, we identify NEOs prior to their discovery (precovery) which provides accurate positional information of NEOs at a different part of their orbit and therefore valuable compared to the existing measurements. These precoveries allow an update of the impact probability of the risky NEOs. Motivated by this result, the talk concludes with a forward look on the value and feasibility of precovery of the hazardous NEOs by expanding our approach to other archives of wide-field imaging instruments/surveys.

KEYWORDS Solar System Objects, Near-earth objects, Astronomical Surveys

FM 10

#1232

Data docking in meteor research

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Meteor science, like any other field of astronomy, collects its knowledge from various surveys of the meteor sky, which are carried out by different methods and different means. Recently, the direction associated with the organization of observations with the help of meteor networks has become especially widespread. Collecting heterogeneous data together and doing a competent analysis of such an assembly is not easy. In such cases, both general recommendations and specific techniques are used. This study is devoted to the experience of dockings in meteor studies. The pros and cons of data stitching in meteor studies will be demonstrated.
Meteor science, like any other field of astronomy, collects its knowledge from various surveys of the meteor sky, which are carried out by different methods and different means. Recently, the direction associated with the organization of observations with the help of meteor networks has become especially widespread. Collecting heterogeneous data together and doing a competent analysis of such an assembly is not easy. In such cases, both general recommendations and specific techniques are used. This study is devoted to the experience of dockings in meteor studies. The pros and cons of data stitching in meteor studies will be demonstrated.

KEYWORDS Meteor, Data docking, Meteor catalogs, Meteor data, Meteor research, Data stitching, Selectivity

FM 10

#619

High precision astrometry of small solar system bodies

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The entire field of small solar system objects relies on the availability of accurate ephemerides: without them, the acquisition of any observation of a known moving object, with any observational technique, becomes impossible. A good ephemeris is the result of an accurate knowledge of the object's orbit and its dynamical evolution, which in turn is based on astrometry, the direct measurement of an object's position at given times.

However, the value of quality astrometry and orbit determination extends beyond the basic production of accurate ephemerides. The study of the dynamics of these objects is intrinsically linked to key current research topics, such as:

- The prediction and prevention of future impacts of near-Earth objects with our planet.
- The study of peculiar populations of objects and their properties (e.g., Atiras, Main Belt Comets, Centaurs and TNOs, interstellar objects).
- The study of non-gravitational effects on small bodies, and how they shed light on specific physical processes.
- The study of the long-term dynamics of the Solar System, with its implications for the origin and evolution of planetary systems in general.
- Indirectly, the possibility of enabling space missions to high-profile objects, both for scientific and planetary defense objectives.

In recent years, our ability to extract accurate astrometry of these bodies has increased dramatically, thanks to the availability of the Gaia stellar catalog. Thanks to its exquisite accuracy, it is now possible to extract high-quality unbiased measurements, in turn improving our ability to model their orbits. New astrometric techniques, such as synthetic tracking, have also changed the way astrometric observations are scheduled and processed, and the hardware required for data acquisition and its analysis.

In this talk, we will briefly discuss some of these key advances, and present some examples of how high-precision astrometry can be crucial to our understanding of the Solar System.

KEYWORDS astrometry, small solar system objects, Gaia, NEOs, orbit determination

FM 10

#2732

The Transneptunian Automated Occultation Survey - TAOS II

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The Transneptunian Automated Occultation Survey (TAOS II) will aim to detect occultations of stars by small (~1 km diameter) objects in the Kuiper Belt and beyond. Such events are very rare (<0.001 events per star per year) and short in duration (~200 ms), so many stars must be monitored at a high readout cadence in order to detect events. TAOS II will operate three 1.3 meter telescopes at the Observatorio Astronómico Nacional at San Pedro Mártir in Baja California, México. With a 2.3 square degree field of view and high-speed cameras comprising CMOS imagers, the survey will monitor 10,000 stars simultaneously with all three telescopes at a readout cadence of 20 Hz. Construction of the site began in the fall of 2013 and was completed in 2017. The custom high-speed CMOS cameras will be delivered in the spring of 2022, and survey operations will commence in the fall of 2022. This talk will give an overview of the survey goals, and the unique capabilities of the TAOS II system and the potential for collaboration with larger ground- and space-based telescopes will be presented.

KEYWORDS TNOs, occultations, telescope arrays, high-speed imaging

FM 10

#2013

Understanding asteroids from their spectra. Asteroid taxonomies: benefits and limitations

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We are currently living in a time with a plethora of space missions to explore minor bodies in the Solar System, covering aspects as different as the testing of kinetic impactor technologies for planetary defense, or the return of samples from the surface of primitive, dark asteroids. Still, when it comes to understand what are minor bodies made of, remote sensing remains the primary method to study their composition: ground-based spectroscopy in the visible-to-infrared wavelengths are the main techniques to determine the presence of different mineral species. The light from the Sun interacts with such minerals and diagnostic absorption bands appear in their reflectance spectra. Measurements of several spectral parameters like slope, the wavelength position of the center of the absorption bands, as well as their depth, or their areas, provide us with valuable information like the relative end-member abundances (weight percentage) and compositions in mineral mixtures, the grain size, or the effects of space weathering. From a statistical point of view, large spectro-photometric surveys obtaining colors of thousands of asteroids (e.g. SDSS, VISTA, J-PLUS) and their associated taxonomies provide us with the "big picture" and perfectly complement the detailed information obtained with spectroscopy. In this talk I will present an overview on the compositional information that can be extracted from visible to infrared spectra of asteroids, as well as the benefits and the limitations on asteroid taxonomies.

KEYWORDS asteroid, spectroscopy, composition, taxonomy

FM 10

#2411

Search for M-type dominated asteroid families

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In the entire terrestrial collection of meteorites, irons compose less than 5%, but at the same time they represent one of the most heterogeneous groups of meteorites in terms of isotopic compositions.The vast majority of iron meteorites belong to only 4 groups, each of which presumably comes from a single parent body. We can expect the presence of at least several families of metallic asteroids formed as a result of catastrophic collisions with the ejection of numerous fragments. Such collisions with numerous fragments should have led to the formation of asteroid families. As it is assumed that the iron meteorite parent bodies can exist among M-type asteroids, we searched for families containing M-type asteroids. The main goal of our analysis was to search for M-type dominated asteroid families. We have analyzed all known asteroid families with more than 100 members according to the Nesvorny database together with their albedos and colors based on the latest version of the WISE catalogue and the new catalog of asteroid brightness measurements, obtained based on the processing of all available SDSS images. Results of our analysis will be presented and discussed.

The work was supported by the National Research Foundation of Ukraine (grant N 2020.02/0371 “Metallic asteroids: search for parent bodies of iron meteorites, sources of extraterrestrial resources”).

KEYWORDS Asteroid family, Iron meteorite, SDSS, albedo, color index

Composition and activity of comets with TRAPPIST telescopes

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TRAPPIST (for TRAnsiting Planets and PlanetesImals Small Telescope) is a set of two twin robotic telescopes with a diameter of 60 cm, funded by the University of Liège and FNRS (Belgium). TRAPPIST-South was installed at La Silla ESO Observatory (Chile) in 2010, and TRAPPIST-North at the Oukaimeden Observatory (Morocco) in 2016. The TRAPPIST telescopes are entirely robotic, equipped with a sensitive CCD camera and a complete set of narrow and broad-band filters. They allow us to measure the production rates of several gas species (OH, NH, CN, C3, and C2) and the dust. With these two telescopes, we follow up comet's activity continuously along their orbit from both Northern and Southern hemispheres. In this work, we present the results of two comets, C/2020 M3 (ATLAS) and C/2017 K2 (PANSTARRS). We analyze their chemical composition and activity evolution over a wide range of distances from the Sun, and on both sides of the perihelion. We measure the production rates of each daughter molecule using the Haser model, in addition to the Afρ parameter to estimate the dust production in the coma. We calculate the ratios of production rates with respect to OH and CN for different molecules as well as the gas/dust ratio. These results allow us to classify the comet in the current taxonomy and better understand the link between comet's chemical compositions and their origins.

KEYWORDS comets, TRAPPIST, robotic telescopes, photometry, C/2017 K2, C/2020 M3, solar system

FM 10

#2396

Asteroid photometry and its interpretation

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Photometric measurements of asteroids are an abundant source of information about asteroids' physical properties. Photometry is available essentially for all known asteroids because it is - together with astrometry - a standard deliverable of automated sky surveys. This sparse-in-time photometry is usually not very accurate, but it is numerous. Apart from sparse photometry, thousands of asteroids have been observed individually to measure their photometric light curves precisely. Because light curves are affected by the shape and spin state of the asteroids, we can reconstruct these basic physical parameters by applying sophisticated inversion methods to photometric data. However, to obtain a unique solution to the inverse problem, that is, a unique sidereal rotation period, spin axis direction, and a convex shape model, photometric observations have to cover a wide range of viewing and illumination geometries. Also, their accuracy has to be such that the light curve signal is not lost in the noise. By applying the light curve inversion method, models of thousands of asteroids have been derived. The rotation period alone was determined for tens of thousands of asteroids. These results represent a statistically significant sample of asteroids that enables us to study the distribution of the spin states and shapes in the whole asteroid population. Analysis of this sample has already revealed correlations between the spin state and the size, family membership, position in the main belt, etc. Detailed non-convex models with surface features can be reconstructed when disk-integrated photometry is combined with disk-resolved data. In my talk, I will review the main results achieved so far and discuss open questions and prospects for the future.

KEYWORDS asteroids, lightcurves, photometry

FM 10
#1120

Significance of shapes and spins in the thermophysical modeling of asteroids

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The advancement and application of thermophysical models (TPMs) as analysis tools for the interpretation of thermal infrared observations have underlined their importance in the studies of asteroid surfaces. Object shape and spin properties are necessary input to most TPMs, as they determine the surface energy budget and temperature calculation. Relatively speaking, a small number of more detailed, non-convex shapes have been modeled using some combination of adaptive optics, radar, and occultation observations. However, there has been a recent spike in the number of convex shapes determined from the inversion of photometric datasets. In addition, a dramatic increase in the number of asteroids observed at infrared wavelengths has motivated research into TPM analysis techniques that do not rely on a priori shape and spin information. These latter two occurrences have resulted in a significant upsurge in the number of asteroids analyzed using TPM techniques. However, the availability of infrared data continues to overshadow the number of asteroids with shape and spin determinations, representing a vast repository of unexplored knowledge.

In this presentation, I will review TPM techniques and investigations from the literature in the context of the significance and importance of an object's shape and spin information. Depending on the shape modeling technique and availability of infrared observations, the determination and accuracy of thermophysical parameters, such as size and thermal inertia, can be affected. Although an increase in detailed non-convex shape models is expected in the next several years, the opportunities to apply TPMs to asteroids using ellipsoid or convex shapes will exponentially rise, due to upcoming large-scale visible and infrared surveys. In this context, will also speculate as to conceivable prospects concerning the interpretation of asteroid surfaces using infrared datasets and the role that future shape modeling efforts will play.

KEYWORDS asteroids, thermal models, shape models, visible photometry, thermal infrared

FM 10
#2391

Asteroid polarimetry in the Gaia era

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Current studies of Small Solar System Bodies take advantage of an unprecedented input of data coming from ground-based observing facilities, from space missions, and from Laboratory activities. Astrometry, Photometry, Spectroscopy, Polarimetry are presently providing an increasingly larger amount of information. The Gaia mission, in particular, is laying the basement for a new era in asteroid investigations, in synergy with other investigations. It is our duty to exploit properly this wealth of information coming from different sources.

After decades of substantial stagnation, due to the poor availability of dedicated instruments and few teams working in the field, asteroid polarimetry

has known in recent years a moment of renaissance. The traditional activities of measurement of the so-called phase-polarisation curves have produced better calibrations of some important relations between polarimetric parameters and physical properties including primarily the geometric albedo and the average size of surface regolith particles. A new class of asteroids exhibiting anomalous polarimetric properties, the so-called "Barbarians" has been discovered, and interpreted in terms of a composition strongly reminiscent of the conditions characterizing the very early phases of planetary growth.

More recently, a polarimetric investigation of the near-Earth asteroid (101955) Bennu, the target of the OSIRIS-REx space probe, has confirmed the possibility to derive from polarimetric data evidence of a possible surface activity, characterizing objects having some affinity with comets. Finally, pioneering investigations in the field of spectropolarimetry suggest that this technique could be another major tool to achieve information about the physical properties of the small bodies in our Solar System. In most general terms, ground-based polarimetric data nicely complement the results of asteroid spectroscopy. This is particularly important in the current situation, in which a very large amount of new asteroid reflectance spectra has been recently published in the third release of Gaia data. A comprehensive analysis of Gaia spectroscopic and photometric data, complemented by ground-based polarimetric data, can open new ways to the efforts of physical characterization of the asteroid population.

KEYWORDS asteroids, polarimetry

Light curve survey of the asteroids with KMTNet

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The studies on the spin state and shape of asteroids provide critical evidence for their origin and evolutionary process. These physical properties can be estimated from the time-series photometry. Therefore, a number of time-series photometric observations of asteroids have so far been conducted for understanding their current physical properties and evolutionary mechanisms. Nonetheless, these studies are tended to be biased towards the short-period and large amplitude objects. To against these observational biases, we conducted an untargeted light curve survey of asteroids employing the Korea Microlensing Telescope Network (KMTNet) 1.6 m telescopes. Our survey was started in the second half of 2019 and monitored the ecliptic plane within a 2° x 14° region of the sky per each night with 25 min cadences. Each field was observed for more than a month to estimate the rotational properties of the long-period asteroids. More than 40,000 asteroids were observed every year and about 3,000 of them were confirmed for their rotation periods. In this talk, we present the typical light curves of asteroids obtained from our survey and a statistical analysis of spin states and shapes of the asteroids from our survey.

KEYWORDS asteroid, photometry, spin state, spin rate, shape

FM 10

#390

Synergy of Small Telescopes for Asteroid (6478) Gault Observations in Tajikistan and Slovakia

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The results of quasi-synchronous optical observations of the asteroid (6478) Gault, carried out on the Zeiss-1000 telescope of the Sanglokh Observatory Institute of Astrophysics NAST and the 1.3-m and 0.61-m telescopes of the Skalnato Pleso observatory of the Astronomical Institute of the Slovak Academy of Sciences in August-October 2020 are presented in this paper. The object episodically shows a signs of cometary activity and therefore is classified as an active main-belt asteroid. As a result of quasi-synchronous observations, it is shown:

- the absolute brightness of the asteroid was 14.42-15.05 (±0.13) and 14.87-15.49 (±0.11) magnitudes in the R and V bands, respectively. According to our images taken a year and a half after the exhibition of increased activity, the brightness of the asteroid has significantly decreased, it may be concluded that we observed it in an inactive stage. Our brightness measurements correspond to the estimates by other observations during this period;

- the light curve indicates the inhomogeneity of the asteroid's surface;
- using Fourier data analysis the upper limit of the asteroid's rotation period is found to be 2.695±0.004 hours;
- asteroid color indices correspond to Q-type asteroids, which are closest in spectral properties to meteorites consisting of ordinary chondrites;
- according to our measurements the estimate of the asteroid diameter is from 2.5 to 3 (±0.13) km and is in good agreement with the estimates of other observations of the same period. Taking into account the observations during the period when the asteroid was not active, we consider this estimate to be the most reliable;
- photometric data of new observations confirm the absence of asteroid activity during the monitoring period. We note a good agreement between the results of our quasi-synchronous observations carried out with different telescopes.

KEYWORDS asteroid, photometry, brightness, light curve, diameter, rotational period

FM 10

#3272

SPECTR - an Optical Spectrophotometer for Transiting Exoplanets

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SPECTR(SPECtrophotometer for TRansmission spectroscopy of exoplanets) is a low-resolution optical spectrograph developed by the Kyungpook National University (KNU) and the Korea Astronomy and Space Science Institute (KASI). This instrument is optimized to obtain the transmission spectra of the star which hosts exoplanets, but it can also be used for general purposes. SPECTR consists of a slit assembly, collimator, mirror, volume phase holographic grism (VPHG), imaging lens, and a CCD camera. They are built to fit into the Cassegrain Interface Module (CIM) of Bohyunsan Optical Astronomy Observatory (BOAO) 1.8 m Cassegrain telescope as cartridges. This allows the use of slit-monitoring, guiding, and calibration systems in the CIM. SPECTR is designed to have a field of view 10' × 4.6', a wavelength range of 380-685 nm, and a resolution of R ~ 250-1500. The slit assembly has 8 slits of width, 1.4", 2", 2.8", 4", 5.4", 8", 12", and 20" with 10' in each length. Direct imaging mode is also available by moving VPHG out of the optical path. We present test observational results on HD 189733b and Qatar-8b during the 2021B and 2022A semesters. Analyses show the SPECTR's capability of simultaneous multi-band photometry with an accuracy of 1 mmag.

KEYWORDS Instrument, Planetary systems, Spectroscopy, Atmospheres

FM 10
#2583

Retrieving Jovian planet atmospheric parameters from broad-band transmission spectra using random forest regression

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Nowadays, the exoplanetary atmosphere study using the transmission spectroscopy technique has been one of the most dynamic fields in exoplanetary research. The availability of large telescopes attached with dedicated spectrographs might be limited to perform transmission spectroscopic studies of all detected exoplanets. Therefore, small telescopes attached with broadband filters might play an important role in covering atmospheric studies of all detected transiting exoplanets. However, one of the main bottlenecks to atmosphere characterisation in this era is the availability of fast and robust atmospheric retrieval. The traditional retrieval methods (e.g. MCMC and nested sampling) require a lot of time to retrieve parameters. Hence, the purpose of this study is to use random forest regression, a supervised machine learning algorithm, to obtain atmosphere characteristics of Jovian planets from broad-band transmission spectra in optical wavelength instead of the traditional method. The random forest regressor has been shown to have the greatest accuracy in predicting planetary radius as well as acceptable accuracy in predicting planetary mass, temperature, and metallicity of the planetary atmosphere. According to the results, random forest regression requires significantly less processing time while producing results comparable to nested sampling retrieval in the PLATON package.

KEYWORDS exoplanetary atmosphere retrieval, transmission spectroscopy, random forest regression

FM 10

#1994

Two circumbinary planets in RR Cae eclipsing binary system

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We present the binary model and the eclipse timing variations of an eclipsing binary RR Cae. RR Cae consists of a white dwarf eclipsed by an M-type dwarf companion with a 4.2 MJup circumbinary planet proposed by Qian et al. (2012). In this work, the multi-band photometry from the 0.7-m Thai Robotic Telescope at Spring Brook Observatory, the 0.6-m PROMPT-8 telescope and Transiting Exoplanet Survey Satellite (TESS) are used to study the eclipse timing variation of the system. The RR Cae parameters are revised using the light curves and the archive radial velocity data from the Very Large Telescope (VLT). The data were analysed using the Markov Chain Monte Carlo (MCMC) on the PHOEBE package. The 430 new eclipse timing obtained from the PHOEBE fitting combined with 32 time of minima from literatures. The eclipse timings are modelled with the light travel time effect due to gravitational interaction from one and two circumbinary object(s). The model prefers the two circumbinary objects model which consists of the planetary mass companions with masses Msin(i) of 3.0 ± 0.3 MJup and 2.7 ± 0.7 MJup with orbital period of 15.0 ± 0.5 and 39 ± 5 years, respectively.

KEYWORDS Close Binary, Eclipsing Binary, RR Cae, Circumbinary Object

FM 10

#1618

A massive companion for a Solar twin

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After the analysis of a series of TESS photometric light curves, we found a massive stellar companion transiting around an old GV2 Solar twin. We analyzed spectroscopic data and carried out an extensive radial velocity extraction follow-up of the system. The latter was performed by high-resolution spectra obtained by the STELLA Echelle Spectrograph (SES) at the robotic 1.2-m STELLA-II telescope in Tenerife, Spain. In addition, simultaneous spectra of the star were taken with the 2x8.4-m Large Binocular Telescope (LBT) in Arizona, USA. The synergy between small and large telescopes allowed us to obtain a robust description of the system by determining and confirming the main stellar and orbital parameters, as well as some activity indicators.

KEYWORDS TESS, STELLA/SES, LBT, Stellar-Companion, Sun-like stars

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#1616

Transmission spectroscopy analyses of Jovian planets in the era of asset-starved

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To date, thousands of exoplanets have been discovered, including a hundred of them which have been detailed studying their atmospheres. The transmission spectroscopy technique has been proven to be one of successful techniques to reveal the atmosphere chemical composition of transiting exoplanets. In order to obtain transmission spectra, the spectroscopic observations using dedicated spectrographs or broad-band photometric observation are required. As the number of exoplanets rapidly increases in recent years after the launch of space-based transit surveys, such as Kepler and TESS, the transmission spectroscopic observations of the exoplanets are currently limited by the availability of observation facilities. While a number of previous studies have already provided the exoplanet parameters, including transit depth which could be used to perform transmission spectroscopic analyses, their fitting tools are different and might not be specifically designed for transmission spectroscopy studies. In this work, thousands of publicly available light curves of more than 160 Jovian planets are collected and reanalysed their physical parameters with TransitFit, a tool designed to fit exoplanet light curves for transmission spectroscopy studies. The transmission spectra of more than 20 planets, which were performed multi-band observations, are analysed for their atmospheric characterizations. The analyses provide the first atmospheric studies on some of such targets, including WASP-15b which found a strong Rayleigh-scattering feature in its atmosphere.

KEYWORDS Exoplanet, Exoplanet atmosphere, Transit, Transmission spectroscopy

FM 10

#1586

Rapidly rotating stars and their transiting planets: KELT-17b, KELT-19Ab, and KELT-21b in the CHEOPS and TESS era

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Rapidly rotating early-type main-sequence stars with transiting planets are interesting in many aspects. Unfortunately, several astrophysical effects in such systems are not well understood yet. Therefore, we performed a photometric mini-survey of three rapidly rotating stars with transiting planets, namely KELT-17b, KELT-19Ab, and KELT-21b, using the Characterising Exoplanets Satellite (CHEOPS), complemented with Transiting Exoplanet Survey Satellite (TESS) data, and spectroscopic data. We aimed at investigating the spin-orbit misalignment and its photometrical signs, therefore the high-quality light curves of the selected objects were tested for transit asymmetry, transit duration variations, and orbital precession. In addition, we performed transit time variation analyses, obtained new stellar parameters, and refined the system parameters. For KELT-17b and KELT-19Ab we obtained significantly smaller planet radius as found before. The gravity-darkening effect is very small compared to the precision of CHEOPS data. We can report only on a tentative detection of the stellar inclination of KELT-21, which is about 60 deg. In KELT-17b and KELT-19Ab we were able to exclude long-term transit duration variations causing orbital precession. The shorter transit duration of KELT-19Ab compared to the discovery paper is probably a consequence of a smaller planet radius. KELT-21b is promising from this viewpoint, but further precise observations are needed. We did not find any convincing evidence for additional objects in the systems.

KEYWORDS methods: observational, techniques: photometric, techniques: spectroscopic, planets and satellites, TESS, CHEOPS, MUSICOS

FM 10

#1183

Multisite and Multimessenger Projects and Campaigns as a Tool to Study of Stars, Star Clusters as well as Solar System and Exoplanetary Bodies

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Despite the significant development of various modern methods for studying various astronomical objects, especially from space observatories, the importance of their direct photometric study by obtaining time series remains relevant. In this sense, the high-altitude Maidanak observatory in Uzbekistan (Cental Asia) has sufficient experience, telescopes and equipment, including the newly acquired Andor state-of-the-art CCD cameras, developing infrastructure, exceptional location and seeing. One of the latest observational campaigns was a multi-messenger monitoring campaign for the cool flare star LP 245-10 = GJ 3147, successfully carried out in November 2021 in cooperation with the observatories of Taiwan, India and China. As part of the international grant program for the search for new and deep study of known variable stars, we also conduct long-term monitoring photometric observations of open star clusters, including young clusters and associations, as well as a number of specific variable stars (EB, MCV,N, SN, PMS and others) in collaboration with colleagues from ARIES (India). We will present the main features and benefits of Maidanak for future campaigns. We are open for any worldwide collaborations in multisite and multimessenger projects and campaigns and could discuss the possibilities as well as the operational strategies through my contact at hojaev@yahoo.com.

KEYWORDS solar system bodies, exoplanets, stars, star clusters, multisite, multimessenger projects/campaign

FM 10

#867

Fireball network BOCOSUR

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The current status of the Fireball/Bolides Network BOCOSUR (Bólidos del Cono Sur), which is being deployed in different locations in Uruguay, is presented, as well as some preliminary results and developed products. The network consists of a set of stations designed and build by us. Each contains a high sensitivity CMOS camera (ASI178MM), fisheye lens (FOV 180 deg), dew prevention systems and PC, all housed within a watertight cabinet.

The stations run an application developed by us, which detects, stores, and sends the videos of one night via FTP to a central server. The bolides detected are subsequently processed with another application, also developed locally, which allows astrometry and photometry of the event to be performed.

The stations have been installed in various public secondary schools in the country. The network currently has 7 operational stations, and 13 more are in the process of being installed. During all stages of deployment (assembly of equipment, installation, operation, and maintenance) the active participation of local educational agents (teachers and high school students) is sought, as well as of undergraduate students of the Bachelor of Astronomy who, together with researchers make up the stable staff of the project.

The general objective of the project is to consolidate a research group, strongly committed to university outreach, which contributes to the characterization of meteor activity at the regional level. Likewise, it seeks to involve local educational communities, with a citizen science approach.

Several tens of fireball has been detected in over a year of operation. Many of them were detected simultaneously from 2-3 stations, which allowed us to compute the pre-atmospheric orbit.

A brief description of the network, of the detection and post-processing applications developed, as well as some primary data based on detections made to date, will be presented.

KEYWORDS fireball, bolides, meteor, allsky, orbits, citizen science

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#614

Constraints on the nearby exoplanet epsilon Indi Ab from deep near- and mid-infrared imaging limits

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Developments in theoretical knowledge as well as instrumentation have, in the past decade, pushed the boundaries of what high-contrast imaging can achieve, both in terms of detection sensitivity and constraining planet properties. Direct imaging surveys in the near-infrared (NIR) and longward wavelengths have proven particularly useful in detecting younger giant planets at wide orbital separations. This scientific work is one such result of an imaging pursuit of the young giant planet, epsilon Ind Ab, which has long eluded NIR imaging surveys in the past, yet revealing its existence via radial velocity trends and astrometry of its Sun-like, parent star, epsilon Ind A. We present results from deep adaptive optics imaging observations of epsilon Ind A with the NaCo (L') and NEAR (10--12.5 microns) instruments at VLT, and derive brightness limits from the non-detection of the companion with both instruments, and interpret the corresponding sensitivity in mass based on both cloudy and cloud-free atmospheric and evolutionary models. For an assumed age of 5 Gyr for the system, we get detectable mass limits as low as 4.4 Mj in NaCo L' and 8.2 Mj in NEAR bands at 1.5 arcsec from the central star. If the age assumed is 1 Gyr, we reach even lower mass limits of 1.7 Mj in NaCo L' and 3.5 Mj in NEAR bands at the same separation. However, based on the dynamical mass estimate (3.25 Mj) and ephemerides from astrometry and RV, we find that the non-detection of the planet in these observations puts a constraint of 2 Gyr on the lower age limit of the system. NaCo offers the highest sensitivity to the planetary companion but the combination with NEAR wavelength range adds a considerable degree of robustness against uncertainties in the atmospheric models. This underlines the benefits of including a broad set of wavelengths for the detection and characterisation of exoplanets in direct imaging studies. The new constraints for epsilon Ind Ab derived in this work set a firm foundation for MIR imaging surveys for the planet in future, especially with the upcoming more sensitive, advanced instruments in the latter half of the decade.

KEYWORDS planets, detection, imaging, solar-type, epsilon Ind Ab

FM 10
#399

The contribution of the modern amateur astronomer to the science of astronomy

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An amateur astronomer in the modern world has the opportunity not only to make visual astronomical observations for own interest, but can make important scientific astronomical observations and make new discoveries in astronomy.

In my example, as amateur astronomer and only through self-education, I describe my discovery of the possible dwarf nova on the old digitized photographic plates of the Palomar Sky Survey, inform about my discoveries of new variable stars from sky surveys data by means of data mining, and also how I discovered: astronomical transient AT 2020quo in the Pan-STARRS images and supernova SN 2022bsi in the CRTS images, planetary nebula candidates in images of the sky surveys and new binary systems in the data of Gaia DR2.

I report about some of my scientific observations using remote telescopes (located at different observatories, in all hemispheres of the Earth): of superhumps of cataclysmic variable stars; of echo outburst of AM CVn star ASASSN-21au; of maximum brightness of blazars; of optical afterglows of gamma-ray bursts; of the M33 microlensing event candidate AT 2021abdj; of rotation of near-Earth asteroid 2022 AB. I also describe my photometric follow-up observations of novae (from the CBAT "Transient Objects Confirmation Page") and my astrometric observations of Solar System objects, including the confirmation of objects posted at the NEO Confirmation Page (for example, asteroid 2020 AV2) and at the Possible Comet Confirmation Page (for example, comet C/2021 A1 (Leonard)) of the Minor Planet Center.

Some of the data obtained by me already used in scientific papers (some of which I wrote alone, one written by professional researchers and I am a co-author), others were sent to the scientific databases (for example, of the AAVSO and of the MPC). I share my experience of discovery and research of astronomical objects and in my example, I show that an amateur astronomer using small telescopes can make a real contribution to the science.

KEYWORDS Data mining, Sky surveys, Astronomical discoveries, Variable stars, Solar System objects, Milky Way objects, Extragalactic objects

Disintegration of Comet C/2019Y4 (Atlas) by Observations in Tajikistan and India

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Long-period comet C/2019Y4 (Atlas) was discovered at the end of 2019. Just before passing the orbit's perihelion on May 31, 2020, at the end of March, observations of the Hubble space telescope have registered a break-up of the comet nucleus into several fragments. To investigate the event quasi-synchronous observations of comet Atlas were carried out in the Cepheid observatory of India, Sanglokh and Hissar astronomical observatories of the Institute of astrophysics, NAST, during March-April 2020. The 0.28 m Schmidt-Cassegrain telescope was used in Cepheid observatory, the Zeiss-1000 and 0.70 m AZT-8 telescopes were applied in Sanglokh and Hissar observatories respectively. Standard broadband filters VRI were used in observations. As a result of photometric processing of obtained images the apparent and absolute brightness of the comet was found in VRI filters and light curves were plotted. The decreasing of the apparent and absolute brightness of comet in VRI bands are shown that confirms the nucleus disintegration occurred at this period. The estimate of the speed of the fragments scattering is several m/s (Green 2020; Hui, Ye 2020), at such speeds the disintegration of the nucleus can be caused by a powerful ejection of gases, which led to the destruction of the mechanical bonds of the conglomerates of the cometary nucleus. The coordinates of comet were determined, the orbit was calculated, and it is shown that the nucleus break-up did not affect the stability of the orbit of the main component of the cometary nucleus.

References:Green D.W.E. CBET 4712: Comet C/2019 Y4 (Atlas), mail.spaceobs.com, (Mailing list), January 11, 2020, retrieved March 25, 2020; Hui M.-T., Ye Q. Observations of disintegrating long-period comet C/2019 Y4 (Atlas) – A sibling of C/1844 Y1 (Great comet), 2020, arXiv: 2004, 10990, [astro-ph.EP].

KEYWORDS comet, photometry, brightness, light curve, astrometry, nucleus, orbit

e-Talks

FM 10

#3225

RDS CCD approach for observations of fast-moving and newly discovered NEAs

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The near-Earth asteroids (NEAs), and particularly those defined as potentially hazardous asteroids (PHAs), pose a serious threat and might have catastrophic consequences in case of a collision with the Earth. Precise orbit determination and reliable assessment of impact probability require enough observational data. The analysis shows that only less than 50% of discovered NEAs were recovered in the next oppositions. In this aspect, it becomes extremely important to perform a successful and long as possible observational campaign for newly discovered NEAs. As a rule, small-sized objects usually are discovered and observed at short distances to the Earth over short orbital arcs. Additionally, they are featured by relatively high apparent rates of motion, complicating their observations. Among newly discovered NEAs in 2019-2020, 10-20% of objects have the last observations 1-2 days before the close approach time moment (CA), and eliminating high apparent rates could extend observed orbital arcs for them.

The Rotating drift-scan CCD (RDS CCD) technique was specifically developed for observations of objects with the high apparent rates of motion and/or when the direction of motion does not coincide with the diurnal motion of the stars. This technique has been implemented at the Lishan telescope (China, MPC code O85) and KT-50 telescope (Ukraine, 089). The arrays of 353 positions for 24 newly discovered NEAs and 257 positions for 23 ones were obtained, respectively, for the last 3 years. The part of observations was obtained around the CA and are the last ones in observed orbital arcs. Such objects usually have big (O-C) differences from zero point at initial analysis. For each obtained array, the mean astrometric precision is around 0.2". The precision of obtained positions is higher than the one for selected observatories and for existing positions in the MPC database in general (~0.5"). Astrometric analysis of obtained results does not show dependency on the apparent rate of motion indicating the reliability of obtained observations and employed observational technique.

KEYWORDS near-Earth asteroids, astrometry, observational methods

FM 10

#2417

The LIFE (Large Interferometer For Exoplanets) mission: status and updates

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The Large Interferometer For Exoplanets (LIFE, https://www.life-space-mission.com) mission concept is a project initiated in Europe with the goal to consolidate various efforts and define a road map that eventually leads to the launch of a large, space-based mid-infrared (MIR) nulling interferometer observatory. This mission will be able to investigate the atmospheric properties of dozens of terrestrial, potentially habitable exoplanets in the Solar neighborhood. In this contribution we present a status report and summarize new results from the LIFE mission initiative.

KEYWORDS exoplanets, life, astrobiology, biosignatures, habitability

FM 10

#2091

SPEARNET - an efficient approach to planetary atmosphere observations using distributed telescope networks

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The Spectroscopy and Photometry of Exoplanet Atmospheres Research Network (SPEARNET) is an international collaboration that is engaged in a long-term statistical study of the atmospheres of hot transiting exoplanets using transmission spectroscopy. We are using a globally distributed heterogeneous network of optical and infrared telescopes with apertures from 0.5-3.6m. We have developed a metric that allows us to optimally pair exoplanet targets to telescope assests within our network, ensuring efficient use of our observing resources. We have also developed a new transit fitiing code that is designed for multi-wavelength, multi-epoch, multi telescope observations of exoplanet targets. In the era of large-scale surveys for relatively nearby transiting planets we will soon be inundated with potential targets for atmospheric characterisation. SPEARNET is piloting a practical and efficient prioritization approach to this formidible challenge. We will discuss both the challenges and opportunities of our approach and provide a status report on the survey.

KEYWORDS exoplanet, atmospheres, optical, infrared

FM 10

#1610

Investigating Transit Timing Variations of the Hot Jupiter HAT-P-37b

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Nowadays, the transit timing variations (TTVs) of transiting exoplanets have been proven to be one of the successful methods to study the dynamics of exoplanetary systems and also detect additional bodies in the systems. In order to analyze the TTV, long-term monitoring of the systems is required which can be covered by networks of small telescopes. Using the small telescope network, we present ground-based photometric observations of the hot Jupiter HAT-P-37b, which is hosted by an G-type star with an orbital period of 2.797 days. The planetary parameters of HAT-P-37b are refined by using both new and published light curves. The analyses for the investigations on the TTV and the upper mass limit for an additional planet are performed. The possibility of an additional planet is inferred by the signal of 1.74-min TTV amplitude. In the case that the additional body is located near the 1:2 mean-motion resonance, the TTV signal could be explained by the gravitational interaction of a sub-Earth mass planet.

KEYWORDS Exoplanet, Photometry, Planetary system, Dynamics of exoplanet

FM 10
#1338

Follow up of TESS Exoplanet candidates using TRAPPIST telescopes

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The Transiting Exoplanets Survey Satellite monitors a large area of the sky to search for thousands of exoplanets around bright stars in the solar neighborhood. A good part of these discoveries can constitute interesting spectroscopic targets for JWST in order to characterize their atmosphere. It provides us with thousands of transit-like signals from candidate planets that need to be confirmed with ground-based facilities as part of the TESS follow-up observing program. We present here our contribution to the seeing-limited photometric follow-up of TESS candidates using our 60 cm robotic telescopes TRAPPIST-North and TRAPPIST-South, and some of the most promising planetary systems that we have confirmed and validated so far.

KEYWORDS Telescopes, Photometry, Exoplanets, Transits, TESS

FM 10
#1477

Synergies Between Survey and Small Telescopes To Reveal Eclipse Timing Variations

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Eclipse timing variations (ETVs) can be crucial to reveal additional bodies around eclipsing binaries otherwise difficult to find. These include circumbinary planets, the number of which is below expectations considering the abundance of binary systems in the galaxy. ETVs help us reveal such bodies at large orbits also balancing the biases favoring the planetary bodies at short-period orbits predominantly detected by radial velocity and transit techniques. Since more massive bodies would induce larger and hence detectable amplitude-ETVs, presence or lack of brown dwarf companions will help us understand the nature of the parameter space so-called the "brown dwarf desert" against the plenitude of stellar companions. Small telescopes owned by amateur astronomers and university observatories are instrumental in revealing the nature of ETVs by filling the gaps in ground-based or space-borne survey data and covering longer timescales. They also play an important role through reconnaissance spectroscopy, radial velocities and multi-band photometry to physically characterize the binary companions. While Kepler, TESS and CHEOPS provide precise photometry from the space, Gaia astrometry will help cover the orbits of such potential companions. On this basis, we are carrying out a survey based on ETVs to look for gravitationally bound yet unseen companions of selected eclipsing binaries. We combine photometry from surveys with the observations from Turkish telescopes ranging in diameters from 0.35 to 1.0 meter-size, stationed in five observatories across the country and from our international collaborators as well as amateur astronomers. The recent discovery of two planetary-mass bodies in the Kepler-451 system (Esmer et al. 2022) within our survey was based on these synergies. We provide our target selection strategies, summarize our timing and auxiliary observations, present the results of our ETV and dynamical stability analyses of selected eclipsing binary systems from our survey within this contribution.

KEYWORDS stars, binaries, planets, photometry, timing, eclipses

FM 10

#739

Observing Variable Stars and Asteroids Using Small Telescopes in UAE

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We present the results of using small telescopes in the United Arab Emirates (UAE) for observing variable stars and asteroids. Two telescopes; 5″ apochromatic refractor and 14″ Schmidt-Cassegrain, at Al-Khatim observatory (M44) were used to do the observations. The targets were the three variable stars: RR GEM, AG LMi and DL CMi and the asteroid 22 Kalliope.

We found a good consistency between our light curves and published ones for the calibration targets; the asteroid 22 Kalliope and the variable star RR GEM.

AG LMi has two suggested periods in the previous studies; these are 16.3 hours and 32.62 hours. Our results clearly confirm the second one with exact period 32.6175 hours.

The star DL CMi has several suggested periods in the previous studies; such as 4.0173 days, 1.9606 days, 2.0086 days. Our observations confirm the first one with exact period 4.0159 days.

The results show the effectiveness of using small telescopes in observing variable stars and asteroids. This work gives some advices on using small telescopes in such observations.

KEYWORDS Variable Stars, Photometry, Small Telescopes in UAE, AG LMi, DL CMi, Kalliope, Al-Khatim Observatory

FM 10

#724

Experiment Observations for the Dwarf Planet Haumea by Small Telescopes in Astrometry and Photometry

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The dwarf planet Haumea is the third largest known trans-Neptunian object after Pluto and Eris. Haumea has two known irregular satellites and its rapid rotation, high albedo and rings are considered as the consequence of a giant collision. We try an experimental observations to Haumea via 1 m telescope in Yunnan Observatory over 4 nights and 80 cm telescope at Yaoan Station, Purple Mountain Observatory over 9 nights from Feb 7th to March 4th, 2022. We perform both astrometry and photometry to the acquired CCD frames for Haumea. For astrometric reduction, the positions from the newest Gaia EDR3 catalog and Jet Propulsion Laboratory Horizons ephemeris are referenced as the theoretical positions for stars and Haumea, respectively. Our astrometric results show that the <O-C>s change ~70 mas and ~110 mas in right ascension and declination, respectively. The errors are estimated at 5-12 and 3-21 mas, respectively. For photometric results, the fitted light-curve from the relative photometry with the assumption of its period of 3.9154 hours shows that the peak difference of the phase is ~0.22 mag with Johnson-I filter. It is worth to research further for the rapid change of positions and photometry.

KEYWORDS Haumea, Astrometry, Photometry, Data Analysis, Dwarf Planet

FM 10
#640

SPFOT Survey for the TESS Space Mission

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Accurate atmospheric parameters and chemical composition of stars play a vital role in characterizing physical parameters of exoplanetary systems and understanding of their formation. The NASA Transiting Exoplanet Survey Satellite (TESS) space telescope will play a very important role in searching of exoplanets around bright stars. In a framework of the Spectroscopic and Photometric Survey of the Northern Sky (SPFOT), we have observed 1266 bright (V < 8 mag) and cooler than F5 spectral class stars in the are centered on the northern TESS continuous viewing zone with a 1.65 m telescope at the Molėtai Astronomical Observatory of Vilnius University and the high-resolution Vilnius University Echelle Spectrograph. The main atmospheric parameters, ages, orbital parameters, velocity components, and precise abundances of 24 chemical species were determined. We investigated the stellar chemical composition and exoplanet mass relation, compared elemental abundances of stars with and without detected planets, and verified elemental abundance versus condensation temperature slopes.

KEYWORDS High-resolution spectroscopy, Small telescopes, Star-planet connection, TESS space mission

FM 10
#431

Assessment of the New Ground-Based Telescope Sharjah Optical Observatory (SOO) with Exoplanet Transit Photometry

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Transit photometry is considered the most functional method used to detect the distant planets that transit between a star and the Earth. By utilizing this method, we present the exoplanet transit phenomena detected by Sharjah Optical Observatory located inside Sharjah Academy for Astronomy, Space Sciences and Technology (SAASST) United Arab Emirates. In this work, we present the profiles for the transited Hot-Jupiter exoplanets: TrES-1b, WASP-104b, and HAT-P-54b. The obtained results have been compared with the results from the first published paper that studied the three Hot-Jupiter exoplanets. The study, in general, focused on attaining several parameters such as orbit inclination, transit duration, and the radius of the planet. The obtained results were (1.205±0.019 RJUP, 1.028 +0.046/ -0.049 RJUP, 1.079 +0.040 / -0.042 RJUP) for exoplanets TrES-1b, HAT-P-54b andWASP-104b respectively, It showed close results to the parameters studied in comparison with the results of the previously published. The rest of the results are included in the tables

KEYWORDS Exoplanet, Transit, Photometry, HAT-P-54b, WASP-104b, TrES-1b

XXXIst General Assembly
International Astronomical Union

IAUGA 2022

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Division A

#3465

IAU Commission A2 "Rotation of the Earth": Current activities and outlook

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The main activities of the IAU Commission A2 (CA2) include coordination of scientific studies on Earth's rotation and related celestial and terrestrial reference frames; improving the theory of Earth's rotation and reference systems and frames; improving the accuracy and understanding of the observed Earth's rotation variations. The CA2 also serves the astronomical community by linking it to the organizations that provide the International Terrestrial and Celestial Reference Systems and Frames and Earth orientation parameters (EOP): the International Association of Geodesy (IAG), the International Earth Rotation and Reference Systems Service (IERS), the International VLBI Service for Geodesy and Astrometry (IVS), the International GNSS Service (IGS), the International Laser Ranging Service (ILRS), and the International DORIS Service (IDS), as well as analyzing and improving consistency between the results delivered by these services. As a result of these studies, several IAU Resolutions were proposed since 2018 and accepted by the IAU, and practical implementation of these Resolutions is underway. In this presentation, we describe and discuss the current activity of the CA2 in these fields and our plans for the nearest future.

KEYWORDS

Division A

#3461

Division A Working Group on Time Metrology Standards (TMS)

Felicitas Arias[1], Working group members (TMS)[2]

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The Working Group on TMS has been created as a functional Working Group of Division A in 2015, with the aim of providing a link between astronomers and the time metrology community that provides the reference timescale. The membership of the WG consists on 18 scientists, experts in the fields of astronomy and time metrology.

Time metrology is going along fundamental changes that will certainly impact on astronomy; the redefinition of Coordinated Universal Time and the redefinition of the SI unit. This talk will present their progress and potential impact on the astronomical science.

KEYWORDS

Division A

#3460

Division A Working Group on Astrometry by Small Ground-Based Telescopes (ASGBT)

Anatoliy Ivantsov[1], Marcelo Assafin[2], William Thuillot[3], Working Group ASGBT members[4]

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[2]*-, Federal University of Reo de Janeiro, Brazil*
[3]*IMCCE, Paris Observatory, France*
[4]*-, -,*

Since the Working Group setup 2006 its goal is disseminating information about the current astrometric programmes and activities carried out with small telescopes (up to 2 m in diameter), distribute the related news, facilitate collaboration and help for coordination of the activities in astrometry from ground-based telescopes. The small telescopes being numerous and geographically widely spread are easily accessible and efficient for observation in networks. The WG members are currently focused on the various projects that get benefits from both direct astrometric measurements of Small Solar System bodies and indirect measurements via photometry of mutual events of natural satellites. Follow up observations of asteroids discovered by the Gaia satellite (Gaia Follow Up Network) are highly necessary for improving their initial orbits and maintaining the discoveries. Astrometry of the optical counterparts of ICRF sources measured at the long-focal telescopes points at the structure, variability of these sources. Digitisation of the photographic archives with high resolution and accuracy supported by the Gaia catalogue data allows to redo the past measurements limited only by the instrument specific errors. We emphasise the efficiency of small telescopes for making astrometric measurements that satisfy the contemporary requirements for getting new discoveries, and encourage visiting the dedicated webpage at https://iau_wgnps.imcce.fr .

KEYWORDS

Division A

#3459

Highlights of IAU Focus Meeting 10: " Synergy of Small Telescopes and Large Surveys for Solar System and Exoplanetary Bodies Research"

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[2]*IMCCE, Paris Observatory, France*

This Focus Meeting is promoting the complementarity of large astronomical surveys and astronomy performed with small telescopes (up to 2 m in diameter). It concerns, in particular, the application of big data methods to modern and past sky surveys, to data archives of small telescope. Machine learning and, in particular, deep learning are used for the classification of exoplanets, enhancing and optimising their follow up observations (TESS). Contemporary and prospective sky surveys (Gaia, LSST, etc.), radar, space-borne data allow to use these highly accurate measurements for calibrating data measured at the small telescopes, revealing their potential in planetary science in the time-domain. We discuss the differential method used at the small telescopes in astrometry, photometry, polarimetry, spectroscopy to complement the scientific output of the sky surveys, e.g., to follow up the newly discovered Solar System objects and exoplanetary systems, expand their physical characterization to different wavebands and properties. Extension of observational histories will positively affect checking the adequacy of various physical and dynamical models, e.g. finding a single solution for the rotation parameters of asteroids that satisfies different observational datasets. The big data methods applied to the sky surveys and small telescope archives have the potential to detect new objects, and to improve classification and data analysis. Data mining sky surveys, astrophotographic plates, and the small telescope archives should substantially increase the completeness of search for the time-domain events. Sharing this experience and advanced observational techniques will enlarge efficiency and facilitate using the small telescopes in conducting the present-day research in Astronomy.

KEYWORDS

Division A
#3458

Astrometry for 21st Century Astronomy

Anthony Brown[1]

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High accuracy astrometry has made spectacular progress over the past decade thanks to developments in VLBI techniques, the appearance on the scene of the GRAVITY instrument, and the giant step taken with the Gaia mission in the quality and depth of its astrometric survey. High accuracy astrometric data is now indispensable across astronomy disciplines and in solar system science. With this focus meeting we wish to highlight the scientific progress based on these astrometric data and bring together the various astrometry and sky survey communities; to learn from each other, explore opportunities for coordination and map out the synergies between astrometry and other techniques and surveys, aiming to maximize the scientific outputs. The IAU GA is the natural venue to bring the communities together and the timing is right, one year after the appearance of the early part of the third Gaia release, three years after the adoption of the ICRF-3, five years into GRAVITY operations, and on the eve of the era of LSST and extremely large telescopes.

Topics are:
Review of modern astrometry and its science applications
Astrometry science highlights, including from Gaia DR2 and Gaia (E)DR3
Future ground and space-based astrometric surveys
Dense and accurate reference frames to optimize the science return from extremely large telescopes and large sky surveys
Astrometric techniques; opportunities for cross-fertilization
Synergies between astrometric, photometric, and spectroscopic surveys

KEYWORDS

Division A

#3457

Pulsar Observation and Study with FAST and Parkes Radio Telescope

Lei Zhang[1]

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Lei Zhang obtained her PhD degree in July 2020 from National Astronomical Observatories, Chinese Academy of Sciences (NAOC). During her Ph.D., she led pioneering work with two major new instruments for radio astronomy, namely the Five-hundred-meter Aperture Spherical radio Telescope (FAST) that is the largest single-dish antenna in the world and new Ultra-Wideband Low (UWL) receiver installed on the Parkes telescope that is the first such receiver to be regularly operated on a major telescope. With only a un-cooled commissioning receiver on FAST, she discovered a new pulsar, J1926-0652, and led the e orts to follow it up with Parkes, GBT, and FAST. Her work revealed a plethora of unexplored complex single-pulse behaviors

and "pose challenges for the classic carousel-type models", as stated in the last sentence of the abstract of the resulting publication (Zhang et al. 2019 ApJ), which was the first international journal paper from FAST. She then focused pulsars in globular clusters (GC). Aided by the then newly installed Parkes UWL, she obtained the most accurate measurements thus far of DM and for the first time RM toward three bright pulsars in 47 Tucanae. This work is a nice example of how to probe GC pulsars with highly-sensitive, well-calibrated observations made available by the UWL. Her work result in one of the first science papers from the Parkes UWL.

KEYWORDS

Division A

#3456

Secular Dynamics of Binaries in Stellar Clusters

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Why do black holes collide? Where are massive planets formed? How are ancient comets able to penetrate the inner Solar System? To address these questions requires a detailed understanding of the orbital evolution of gravitationally bound two-body systems — usually known as binaries.

Despite the great diversity of astrophysical binaries, many of them share the common feature that they are not isolated, but are instead continually perturbed by their environment, such as their host star cluster or galaxy. Here I derive a general theory that describes the orbital evolution of any

binary system perturbed by an external gravitational field. When applied to black hole binaries in star clusters the theory explains how the force from the cluster can ultimately drive the black holes to merge. Furthermore, the theory constitutes a generalisation of the classical three-body problem, and despite centuries of work on that topic, in almost every Chapter of the thesis I reveal some new insight into it.

In summary, then, the purpose of this thesis is three-fold: to formulate a unified theory of binary dynamical evolution; to propose an origin for black hole mergers and other astrophysical exotica; and to uncover a range of new, important and beautiful dynamical phenomena.

KEYWORDS

Division A

#2939

Searching for scalar field dark matter with the DAMNED experiment

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DArk Matter from Non Equal Delays" (DAMNED) is a new experiment that aims to detect dark matter. This 3 arms Mach-Zender experiment allows us to compare an ultra-stable cavity to itself in the past through the delay created by a multi kilometer long optical fiber. We present the results of this new experiment and put competitive constraints on the DM coupling constants.

KEYWORDS Dark matter, Interferometry, experiment

Astronomy for All
Busan 2022

Division A

#2612

A new general relativistic planetary orbitography platform

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[2]*Geodesy Observatory of Tahiti, University of French Polynesia, Polynesia*

Through a series of resolutions, the International Astronomical Union suggest that all problems in the field of astronomy or astrodynamics be formulated within the framework of Einstein's general theory of relativity.

Orbitography software such as the French space agency GINS or NASA's MONTE platforms currently describe the motion of interplanetary spacecraft using a classical Newtonian framework linearly corrected with effective forces, accounting for the effects of general relativity with the so-called n-body Einstein-Infeld-Hoffmann (EIH) equations of motion. Given the stringent accuracy requirements associated with fields such as astrometry, metrology and geodesy, spacecraft propagation platforms based on the so-called ``Newton $+$ correction'' framework need to include subtle relativistic effects in order to reflect the rapid improvements in modern measurement technology. We argue that this approach is now reaching its limits in terms of complexity.

Recently [1,2] we presented the first results of a prototype software titled General Relativistic Accelerometer-based Propagation Environment (GRAPE) which describes the motion of interplanetary probes and spacecraft using the complete framework of general relativity. GRAPE employs extended relativistic equations of motion which account for non-gravitational forces using either end-user supplied accelerometer data or approximate dynamical models.

In this talk, we extend GRAPE for operational mission planning within the Solar System, describe the approach adopted to interface it with NASA's SPICE kernels and verify our results by comparing the Doppler residuals using GRAPE and SPICE with high-precision Ka/Ka band Doppler data obtained from the gravitational-wave experiments performed by the Cassini probe during its cruise phase.

[1] O'Leary, J. and Barriot, J.P., 2021. An application of symplectic integration for general relativistic planetary orbitography subject to non-gravitational forces. Celestial Mechanics and Dynamical Astronomy, 133(11), pp.1-22.

[2] O'Leary, J., 2021. General Relativistic and Post-Newtonian Dynamics for Near-Earth Objects and Solar System Bodies. Springer Nature.

KEYWORDS General Relativity, Planetary Orbitograhy, Non-gravitational Forces, Interplanetary Navigation

Division A

#1984

Advances and prospects in the accurate modeling of precession-nutation from VLBI solutions

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The celestial pole offsets (CPO), or deviations of the observed celestial intermediate pole with respect to the nutation IAU2000 and precession IAU2006 current theories, can be accurately determined only from VLBI data. Most CPO solutions compute the pair dX, dY, using a session-wise approach from each 1-day long observation "R" session. The weighted root mean squared (WRMS) of CPO time series is the most common measure of the accuracy of the a priori models.Improving such accuracy was urged by IAU Resolution B2 in 2021, and we address how that requirement may be implemented at short-term.

This presentation intends to exemplify to which extent the unexplained variance of CPO observed by VLBI can be reduced by the option of using some corrections to the precession and forced nutations models, including modifying the a priori in the solution computation. As an example, a suitable update of the precession offsets and rates of IAU2006 allows to reduce the WRMS of dX and dY from the IVS ivs19q4X combined solution in 1984-2021 from 173 and 174 μas to 153 and 159 μas, respectively. This is not the only chance of improving the accuracy of this precession theory. Moreover, the unexplained variance may be further reduced by introducing a suitable set of corrections to the IAU2000 nutation models, whose fit is over 20 years old but still provides the a priori standard to compute the nutations when analyzing VLBI data.

A complete revision of the nutation theory seems to be the best way of increasing accuracy and consistency with all the IAU current standards, but it is not feasible at the short term, given its complexity. The possibilities explored so far include partial re-fitting of the IAU2000 theory, meant as updating the MHB2000 transfer function but not second-order or oceanic effects among others, derivation of empirical corrections to the amplitudes of selected sets of astronomic periods, and also combinations of theoretical and empirical corrections.

KEYWORDS Precession-nutation, VLBI solutions, Earth rotation, reference systems

Astronomy for All
Busan 2022

Division A
#1254

Effects of the mass redistribution on the rotation of the Earth

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As a consequence of the tidal attraction of the Moon and the Sun the Earth suffers a redistribution of mass. In turn, such redistribution gives raise to an additional contribution to the Earth gravitational potential energy: the redistribution potential. In the last few years we have performed a comprehensively study of the influence of that effect on the Earth rotation —Baenas, Escapa, & Ferrandiz 2019, 2020, 2021 (published in A&A). These works address the precession, nutation, and secular changes in length of day.

In this talk, we present the framework employed to derive all such effects stemming from the redistribution potential. It is based on the Hamiltonian formalism and presents the advantage of leading to analytical formulae of the induced contributions. That is especially useful, since it facilitates the evaluation of the effects of different sets available for frequency-dependent Love numbers corresponding to solid and oceanic tides.

In this way, we compute the derived formulae using IERS Conventions 2010 frequency-dependent Love number set for solid tides (with oceanic load), and Williams & Boggs (2016) correction to account for the direct contribution of the oceans. Secular length of day variation is in very good agreement with recent observational values.

The obtained numerical values for precession and nutation, however, show significant discrepancies with those of IAU2006 and IAU2000 standard models. This fact must be considered in the revision of IAU models of precession and nutation. In addition, due to the magnitude of the contribution related to the ocean and for keeping consistency, the ocean model adopted in IERS and GGOS Conventions should be the same as that used in the development of precession and nutation theories.

KEYWORDS Precession, nutation, length of day, rotation of the Earth, celestial mechanics, reference systems

Division A

#1288

Astronomy from the Moon Surface and ILOA Hawaii

Steve Durst[1]

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The Moon's thin exosphere, radio quiet farside, stabile surface, 1/6th gravity, extractable volatiles for ISRU and near-term human settlement allowing for instrument services/upgrades make the Moon an attractive environment for a wide-range of astrophysical observation including long duration, high resolution Earth observation, parallax astrometric measurement, interferometry / VLBI, and classical refractor and reflector telescopes.

International Lunar Observatory Association (ILOA) is preparing its first lunar payload, precursor ILO-X, to land on the Moon near 24.5°N, 50.5°W / Vallis Schröteri aboard Intuitive Machines IM-1 Nova-C lander in 2022 via SpaceX Falcon 9 rocket.

The <600g ILO-X dual instrument astronomy lenses, one narrow and one wide FoV built by Canadensys of Ontario, Canada, will conduct optical First Light images of the Milky Way Galaxy Center, and other observations, while serving as technology demonstrators. To date 7 Invited Observations for global collaboration with ILO-X are in place, and ILOA hopes to enable global outreach of its observations with the nearly 8 Billion people of Earth.

ILOA Flagship ILO-1 planning is underway, possibly involving radio and other astronomical spectroscopy instruments. Malapert Mountain, near the Moon South Pole is the ideal location for ILO-1. It's backup, ILO-2 is likely destined for Shackleton Rim or Malapert Mountain. Other 2022 missions are CAPSTONE, Artemis 1 / SLS, Astrobotic Peregine-1, India Chandrayaan-3, Russia Luna-25, Korea Pathfinder Lunar Orbiter (KPLO), Japan ispace, JAXA SLIM and IM-2.

ILOA Hawai'i continues collaborations with China 2013 Chang'e-3 Lunar-based Ultraviolet Telescope (LUT), is planning for at least 5 Galaxy Forum 21st Century education events in 2022, and advocates for a peaceful, aloha-spirit human return to the Moon / First Woman on the Moon – who will undoubtably 'look up' to observe the sky, performing amateur astronomy from their first steps on Luna.

KEYWORDS Astronomy, Moon, Milky Way Galaxy, Observation

Division A
#1242

Sequentially Estimating and Updating Terrestrial Reference Frames

Richard Gross[1]

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The terrestrial reference frame (TRF) is the foundation for virtually all space-based and ground-based Earth observations. Positions of objects are determined within an underlying TRF and the accuracy with which objects can be positioned ultimately depends on the accuracy of the TRF.

The terrestrial reference frame is determined and maintained though a global network of ground sites with co-located SLR, VLBI, GNSS, and DORIS stations and is realized as the international standard through the ITRF (International Terrestrial Reference Frame). Requirements for the ITRF have increased dramatically since the 1980s. Today, the most stringent requirement comes from critical sea level programs: a global accuracy of 1.0 mm, and 0.1 mm/yr stability is required. This is a factor of 5 to 10 beyond current capability. Current and future satellites will have ever-increasing measurement capability and should lead to increasingly sophisticated models of the processes that they are observing. The accuracy and stability of the terrestrial reference frame needs to dramatically improve in order to fully realize the measurement potential of the current and future generation of Earth observing satellites.

Recent ITRFs have been produced at intervals of 3-6 years (ITRF2000, ITRF2005, ITRF2008, ITRF2014, ITRF2020). Between these realizations, users must rely on predictions of the motions of the reference stations that make-up the ITRFs. However, these predictions degrade with time leading to errors in products that depend on the ITRF. Updating the TRF more frequently would eliminate the need for multi-year predictions and hence eliminate this source of error in the TRFs.

JPL is developing a sequential estimation approach to realizing terrestrial reference frames. This approach, which was used at JPL to produce JTRF2014 and which is being used to produce JTRF2020, and which is particularly well-suited to the task of updating the TRF in a timely manner, will be described in this presentation.

KEYWORDS Terrestrial Reference Frame, VLBI, GNSS, SLR, DORIS

Division A

#694

Preliminary study on the consistency among hydrological angular momentum estimates determined from CMIP6 historical simulations

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Polar motion (PM) is an essential parameter needed to transform coordinates between celestial and terrestrial reference frames, thus playing a crucial role in precise positioning and navigation. Geophysical interpretation of PM variations is an important, but still challenging task. Hydrological signals in particular are a source of uncertainty in the estimation of geophysical excitation of PM.

In this study, we use data obtained from sixth phase of the Coupled Model Intercomparison Project (CMIP6) to assess the impact of the continental hydrosphere on PM excitation. To do so, we exploit soil moisture and snow water variables taken from historical simulations of CMIP6 to estimate hydrological angular momentum (HAM) series. There is a wide variety of climate models delivered in the frame of CMIP6, which differ in terms of initial conditions, physical properties of atmosphere, oceans, hydrosphere, and climate forcing. Such divergences obviously contribute to the differences between various CMIP6-based HAM series. In order to determine how large the spread of results obtained from climate models can be, we study the consistency among CMIP6-based HAM with respect to the mean of all considered models. We will split initial set of 99 models into groups taking into account the course and amplitudes of estimated HAM series. We also evaluate various CMIP6-based HAM series with the use of hydrological signal in geodetically observed PM excitation. The general conclusion is that despite the large differences between the HAM series obtained from CMIP6, it is possible to choose the models that allow for quite reliable determination of HAM.

KEYWORDS Polar motion, Climate, EOP

e-Posters

Division A

#2881

New Data on the Eclipsing Binary V1848 Ori and Improved Orbital and Light Curve Solutions

Faezeh Jahediparizi[1]

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New observations of the eclipsing binary system V1848 Ori were carried out using the V filter resulting in a determination of new times of minima and new ephemeris were obtained. We presented the first complete analysis of the system's orbital period behavior and analysis of O-C diagram done by the GA and MCMC approaches in OCFit code. The O-C diagram demonstrates a sinusoidal trend in the data; this trend suggests a cyclic change caused by the LITE effect with a period of 10.57 years and an amplitude of 7.182 minutes. It appears that there is a third body with mass function of f (m3) = 0.0058 $M_\odot$ in this binary system. The light curves were analyzed using the Wilson-Devinney code to determine some geometrical and physical parameters of the system. These results show that V1848 Ori is a contact W UMa binary system with the mass ratio of q = 0.76 and a weak fillout factor of 5.8%. The O'Connell effect was not seen in the light curve and there is no need to add spot.

KEYWORDS photometry, ephemeris, sinusoidal, individual: V1848 Ori

DIVISION B

Facilities, Technologies and Data Science

Invited & Contributed Talks

Division B

#3466

Spectropolarimetric and imaging properties of Fabry-Pérot etalons. Applications to solar instruments

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The use of Fabry-Pérot etalons as tunable narrow-band filters has consolidated over the last decades in solar instrumentation. The reason for their popularity lies on their capabilities to offer both a high spectral resolution and a field of view much larger than the one provided by conventional slit-based spectrographs. The spectropolarimetric and imaging properties of such instruments is dominated by the quality of the etalon and the type of illumination they receive (collimated or telecentric). However, their performance has been evaluated in most studies only to some extent —e.g., assuming purely monochromatic effects, isotropy, or ideal illumination—. Such an incomplete consideration on the impact of etalons has led to an endless and biased debate about their optimum arrangement in solar spectropolarimeters (collimated or telecentric).

In this work we address the spectral, polarimetric, and imaging features of Fabry-Pérot etalons and their influence in solar instrumentation in both collimated and telecentric configurations with especial considerations on (i) the effect on the finite passband of the etalon on the observations, (ii) possible birefringent effects appearing in solid etalons, (iii) imperfections on the illumination in both collimated and telecentric mounts and (iv) the impact of etalon defects on the spectral, polarimetric and imaging capabilities of the instruments. We present useful tools to determine not only the type of configuration that suits the best for each particular instrument, but also to set the requirements on the optical parameters, tolerances and quality of the etalons to be employed. We therefore aim to provide farther insight on the assessment of the performance of current instruments and on the design of future instrumentation with the highest sensitivity.

KEYWORDS

Division B

#260

Laboratory studies of interstellar methane ice in the era of JWST

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Methane (CH4) is a simple organic that is widespread across our universe. It is one of the most abundant ices to be detected in the interstellar medium (ISM), and its D/H signature probed on planetary satellites suggests interstellar inheritance of methane by our Solar System. Despite its ubiquitous nature, there are still considerable lapses in our knowledge of interstellar methane. Technical difficulties in astronomical observations (telluric contamination), laboratory experiments (working with carbon atoms), and even computational efforts (inclusion of H2, a precursor of methane) have hindered our full understanding of it. In this contribution, I discuss recent laboratory experiments conducted at Leiden University and NASA Goddard Space Flight Center on interstellar methane ice, as timely for the James Webb Space Telescope (JWST) – an ideal facility to probe methane ice due to being spaceborne and having ice mapping capabilities. Such experiments include the first demonstration of methane formed by the sequential hydrogenation of C in a water-rich ice, as assumed in models for decades but never confirmed. Experimental confirmation of this formation route provides values such as formation yields and rates, and shows that the inclusion of water leads to twice the methane formation rate. Another relevant, yet overlooked route to methane formation is also discussed: C + H2 in a water-rich ice. Finally, I discuss quantitative and qualitative results on the effects of radiation on the D/H ratios of methane embedded in water ice. Notably, a CH4 to CH3D yield of at least 75% demonstrates the effectiveness of radiolysis on isotope exchange, and therefore should be included in models to more accurately interpret the D/H ratios of interstellar or interstellar-inherited methane ice.

KEYWORDS Interstellar, Ice, Infrared, Astrochemistry, Solid-state, Laboratory, UHV

Division B

#1256

Exact wide-field interferometric imaging via distributed sparse image reconstruction

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Low-frequency radio interferometric telescopes, made from non-coplanar antenna arrays, have extremely wide fields of view (~ 30°). To perform wide-field imaging, the w-projection algorithm models wide fields of view with the non-coplanar w-term. However, calculating the exact model for each measurement has been limited due to the amount of computation required at high resolution and the large volume of data from current interferometers. The required accuracy and computational cost of these corrections are one of the largest unsolved challenges facing next-generation radio interferometers such as the Square Kilometre Array. We show that the same calculation can be performed with a radially symmetric w-projection kernel, where we use one-dimensional adaptive quadrature to calculate the resulting Hankel transform, decreasing the computation required for kernel generation by several orders of magnitude, whilst preserving the accuracy. We demonstrate the potential of our radially symmetric w-projection kernel via sparse image reconstruction. We develop an MPI distributed w-stacking and w-projection hybrid algorithm, where we apply exact w-term corrections for 100 million measurements.

KEYWORDS techniques: image processing, radio continuum: general, techniques: interferometric

Division B

#1145

The astrochemical factory: Producing the first biomolecule building blocks

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Star-forming regions are teeming with molecules, including some that are considered biomolecule building blocks. Species such as CH3NCO, CH3NH2, HOCH2CHO can form peptide chains, amino acids, and sugars, respectively. Formation of these molecules in space and their subsequent delivery to newly formed planets, by comets or asteroids, helps kick-start prebiotic chemistry and early biochemistry.

But how do these building blocks of biomolecules form in the first place? Largely this is the task of the astrochemical factory: The ice coated dust grains in interstellar space where efficient chemical reactions take place. In this presentation we will take a look at the laboratory experiments that simulate this ice chemistry and are used to elucidate the formation of peptide chain building blocks in space, such as CH3NCO. These laboratory results are used to interpret instellar observations of molecular inventories with radio telescopes, such as ALMA. From the combined laboratory and observational studies, we see a picture emerging of an extensive and efficient ice chemistry in space that is responsible for the formation of many biomolecule building blocks and for which its origin can be traced back to the dark cloud stage, the start of star formation.

KEYWORDS Astrochemistry, Prebiotic, Molecules, Star Formation

Division B

#806

The Iranian National Observatory 3.4m optical telescope

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Iranian National Observatory (INO) project is in the final stage of completion, following the installation of the telescope mount and the enclosure dome in 2021. The observatory is located in central Iran on Mt Gargash at 3600m above sea level. The site benefits from an excellent atmospheric seeing (~0.7 arcsec FWHM) and suitable weather conditions. The initial verifications at the site suggest that the telescope and the dome perform according to the design specifications. The observatory comprises of the 3.4m optical telescope, its enclosure and auxiliary equipment, service building hosting control room, offices and mirror handling/coating hall, vacuum mirror coating system, site monitoring station equipped with a weather station and an automatic seeing monitor, a telephoto lens array system for wide-field monitoring, and essential utilities. The primary mirror is placed 13m above the site level, a requirement from microthermal analysis to avoid ground layer turbulence. The Alt-Az type telescope mount benefits from hydrostatic bearing in the Azimuth axis, active optics for the primary mirror support, and a hexapod to support the secondary mirror. The instrument adapter hosts an auto-guiding unit and the wavefront sensor, which serves the active topics. Due to the adapter design, up to three instruments can amount on the telescope, which can feed imagers and spectrographs on the main Cassegrain stations and the two side stations. This choice allows a switch between the instruments in a short timescale, enabling the facility to respond to transient events to take advantage of the longitudinal location of the observatory in the northern hemisphere. The dome is 16m in diameter and benefits from large air flushing windows, wind and moon screens and a cooling system to maintain the target mirror temperature during the day and minimise the seeing degradation.

KEYWORDS Observatory, Telescope, Iranian National Observatory, Telescope dome, Coating, telephoto

Division B

#710

The Commensal Radio Astronomy FAST Survey (CRAFTS) and its Discovery Potential

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The Five-hundred-meter Aperture Spherical radio Telescope (FAST) has been in operation for two years and starts to become available to the international community. Motivated by the great Arecibo observatory, FAST achieves the best instantaneous sensitivity in L-band. Through a combination of PI programs and large surveys, FAST data have resulted in more than 120 peer-reviewed publications, including more than 7 on high impact journals, such as Nature, Science, and Nature Astronomy. Based on a novel high-cadence CAL injection scheme, we have designed the Commensal Radio Astronomy FAST Survey (CRAFTS), which realizes, for the first time at any major facility, simulataneous data recording of pulsar search, HI imaging, HI galaxies, and transidents (FRB and SETI). Utilizing the FAST L-band Array of 19-beams (FLAN) and the drift-scan mode, CRAFTS improves the FAST's survey efficiency significantly. Asipiring to cover the sky accessible to FAST, roughly 58% of the full sky, CRAFTS could discover ~1000 pulsars and 0.5 million galaxies as well as obtain ~10 billion voxels of HI images. With over 15% completed, CRAFTS has discovered 160 pulsars including the FAST's first double-neutron-star system and 6 new FRBs. Initial HI imaging and HI galaxy results are close to publication. I will discuss some of the science highlights so far as well as the challenges of dealing with multiple petabytes of data every year.

KEYWORDS FAST, radio telescope, commensal, HI, pulsars

Division B

#355

Imaging X-ray Polarimeter Explorer (IXPE) first results

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The Imaging X-ray Polarimetry Explorer (IXPE) was launched on December 9, 2021, reopening, after more than 40 years, the polarimetric window in the classical X-ray band. In this talk I will describe the main IXPE characteristics, discuss science prospects and report on first results.

KEYWORDS X-rays, Polarimetry

Division B

#1044

SKAO and SRC Data Reduction

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The Square Kilometre Array Observatory is a world class radio observatory, and came into force as an intergovernmental organisation in May 2021 headquartered in the UK, with construction ongoing in South Africa and Australia. When the telescopes are operational (circa 2028), they will be producing data at unprecedented rates from the two sites, with data reduction taking place through the central signal processors and science data processors to build the Observatory data products. The high data rates prevent data storage at the early stages and, with the data processing subject to scheduling and load balancing constraints, the data reduction pipelines need to be robust, reliable and predictable.

The Observatory data product delivery is not the end of the data lifecycle; it is the starting point for a new, interesting journey for the data to end user access via the SKA Regional Centres (SRCs). The SKA Community is working alongside the Observatory to define an operational SKAO/SRC design and collaboration model, placing an emphasis on interoperability. The SRCs will serve as the gateway between the science users and SKA data products in order to maximise the science output of the Observatory. A number of national SRC development projects are currently underway.

As scientists shift away from data processing and retrieval from "near" the telescope, to interacting with SKAO data products delivered by the Observatory via SRCs, building trust in the user community will be paramount. Users must know how their data products have been generated and what tools are available to interact with, and extract science from, them. This is a technical design challenge but also a social one, with significant effort needed to establish trust within the user community. Efficient delivery of Observatory data products to the SRCs is just step one, with the ultimate purpose of a well-designed network of SRCs being to maximise science delivery from the SKA Observatory.

KEYWORDS SKAO, SRC, Data management, User community, Cloud computing, Big Data

Division B

#1130

Radio astronomy developments in Republic of Korea

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Radio astronomy in Korea was started by Dr. Young-Key Min who majored in radio astronomy in the United States and was appointed as the first director of the Korea National Astronomical Observatory in 1975. Centered on him, the construction plan of the Taeduk 14m radio telescope that can be operated at the millimeter-wave band was promoted from the late 1970s, and the system was installed in 1986. Although in this initial stage of operation, there were many difficulties because there were no professional engineers as well as very few doctors in radio astronomy in Korea, observational studies could be carried out in earnest with the accumulation of operational experience and reinforcement of professional manpower cultivated from domestic and foreign universities, and a next new project with global competitiveness was discussed from the mid-1990s.

In 2000, the Korean VLBI Network (KVN) project that can be simultaneously operated at four bands of 22/43/86/129 GHz was approved by the government. In 2012, scientific researches for star forming regions, evolved stars, and active galactic nuclei etc. were started using the KVN. Since then, KVN has been also operated as a joint network called KaVA (KVN + Japanese VLBI network VERA) and EAVN (East Asia VLBI Network including Chinese radio telescopes) while conducting each Key Science Program or Large Program. The Korean radio astronomy community centered on Korea Astronomy and Space Science Institute (KASI) has been also joining in the ALMA project as a member of the East Asia ALMA consortium from 2014 and joining in the East Asian Observatory (EAO) JCMT operation including the Event Horizon Telescope (EHT) project.

As a future prospect, there will be two important directions for the development of radio astronomy in Korea. One direction will be to pursue global competitiveness in the science and technology of radio astronomy based on domestic research and technology connected with KVN and Extended-KVN from the 14m telescope at mm wavelength. The other direction will be to pursue global competitiveness through international cooperation in the world's most advanced large-scale observation facilities such as ALMA, SKA and ngVLA etc.

KEYWORDS Radio astronomy in Korea, Taeduk 14m radio telescope, Korean VLBI Network(KVN), KaVA, EAVN, ALMA, Global competitiveness

Division B
#708

History of Radio Interferometers in Japan

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Radio astronomy in Japan began in the late 1940s. Because the second-hand military radar equipment was converted to a radio telescope, the observing wavelengths were limited to the centimeter wavelengths. Minoru Oda and his group at Osaka University started continuous observation of the Sun at 3.3 GHz. In 1950, his group proposed the concept of a radio interferometer with 5X5 horn antennas, a total of 25 antennas arranged in a grid pattern, but it was never actually built.

Inspired by the concept by Oda's group, Haruo Tanaka and Takakiyo Kakinuma built a radio interferometer of five 1.5-m antennas at 4GHz in 1953 at the Research Institute of Atmospherics of Nagoya University in Toyokawa. This was the first radio interferometer built in Japan. The radio interferometers at Toyokawa evolved into two-dimensional arrays (radio heliographs) with 48 and 49 antennas at the wavelengths of 3 cm (in 1970) and 8 cm (in 1975), respectively.

Meanwhile, the radio astronomy group at the Tokyo Astronomical Observatory had been concentrating on the solar observations at the meter wavelengths and constructed the 160MHz solar radio interferometer with 17 antennas of 6m~8m diameter at the Nobeyama site 1n 1969. In 1992, the accumulation of the technologies for solar radio interferometers developed at Toyokawa and Nobeyama was finally culminated in the 17GHz/35GHz Nobeyama Radio Heliograph which consisted of 84 80-cm antennas.

In the field of cosmic radio astronomy, the Nobeyama Millimeter Array (NMA) with five 10-m antennas was constructed in 1982 at the Nobeyama site. The NMA, the first millimeter wave interferometer in Japan, served as an important step toward the ALMA project.

This paper reviews the history of the radio interferometers developed in Japan mainly from the 1950s to the 1980s.

KEYWORDS *radio astronomy, radio interferometer, radio telescope, Japan*

Division B

#704

Development of VLBI in Japan

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The history of VLBI development in Japan is reviewed. VLBI research in Japan began in 1975 with the development of a VLBI system at the Radio Research Laboratory Kashima (now the Kashima Branch of NICT). In 1985, geodetic VLBI observations with Hawaii successfully measured the movement of the Pacific Plate. Subsequently, when the 45-m telescope at the Nobeyama Radio Observatory of the Tokyo Observatory (now the National Astronomical Observatory of Japan NAOJ) started operating in 1982, global VLBI observations at 1.3 cm and 7 mm were begun with the active galactic nucleus research and others. Furthermore, the Institute of Space and Astronautical Science and NAOJ jointly developed the first space VLBI satellite (HALCA), which was launched in 1997 and conducted joint observations with ground VLBI stations as the VSOP programme until 2005. In 2001, the VERA project was started by NAOJ with two-beam phase-referencing observations and elucidated the structure and motion of the Milky Way Galaxy by astrometry observations. The construction of the East Asian VLBI Observation Network, which combines the VLBI observation networks of Japan, Korea and China, has also been promoted, and open-use observations have started in 2018. Since 2002, Yamaguchi University and Ibaraki University have converted the existing 32-m antenna for communications into a VLBI station, and VLBI observations of methanol maser sources have been carried out. In geodetic VLBI, the Key Stone Project was launched by NICT in 1995, and real-time VLBI observations were carried out by optical fibre data transmission and measured crustal deformation around Tokyo in real time. The GSI (Geospatial Information Authority of Japan) has been participating IVS observations in 1992 and built the Tsukuba 32-m radio telescope in 1998, which has continued; in 2015, the Ishioka 13.2-m station was built to meet VGOS observation specifications.

KEYWORDS VLBI, Development, History, Japan

History of Space-VLBI in Japan

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Japan made a unique contribution to space-VLBI, the history of which is described.

1. Nobeyama Radio Observatory, with a 45m radio telescope opened in 1982. UDSC, the Usuda Deep Space Center of ISAS, equipped with a 64m antenna was dedicated in 1984. The two sites are only about 20km apart. In the 1980s, discussions between the Nobeyama Radio Observatory and ISAS started, to consider a space-VLBI mission. The JPL group joined the discussion, and the mission became more realistic and scientifically valuable.
2. The TDRSS-OVLBI experiment was successfully conducted by US, Japan and Australia at S-band in 1986, and at 15GHz band in 1988. The 64m and the 45m antenna joined the experiments.
3. VSOP Mission was approved in April 1989, with the M-V launcher then under development. The satellite name was Muses-B, under the Mu Scientific and Experimental Satellite series. The five tracking stations and the VSOP correlator were made in time. VISC (VSOP International Science Council) was formed.
4. The Muses-B was launched successfully, and was re-named HALCA on Feb.12 1997. The first fringes were obtained in July 1997, and the first image in August.
5. The VSOP mission was scientifically open in October 1997. After about 3 years, HALCA started to have pointing problem, and was powered off in November 2006.
6. VSOP-2 mission was approved in April 2007. But the design was critically reviewed later, and the project was cancelled in 2011.

KEYWORDS VSOP, space-VLBI, HALCA, Muses-B

Division B

#2833

Transforming our knowledge of the radio sky with ASKAP

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The Australian Square Kilometre Array Pathfinder (ASKAP) is a novel phased array feed (PAF) telescope located on the Murchison Radio-astronomy Observatory in Western Australia. ASKAP consists of 36 antennas, each equipped with a 188-element PAF operating in the range 0.7–1.8 GHz with instantaneous bandwidth of 288 MHz. The antenna configuration has baselines from 22 m to 6 km, supporting imaging with a resolution of 10 arcseconds and an instantaneous field of view of 31 square degrees at 0.8 MHz.

ASKAP has recently completed its first all-sky survey (the Rapid ASKAP Continuum Survey, RACS) and several pilot surveys, which were designed to prepare for a dedicated 5-year transformational survey campaign. These full-scale surveys include continuum, spectral line, polarimetric and time-domain components and are scheduled to begin in October 2022.

ASKAP also features a real-time fast transient detection system that has discovered many Fast Radio Bursts. A new GPU-based coherent time-domain analysis system is being developed to improve ASKAP's fast transient sensitivity by a factor of 5 and facilitate near-real-time follow-up observations, including with the Australia Telescope Compact Array.

We will describe the performance of ASKAP, results from the pilot programs, and outline the principal scientific programs of ASKAP for the next five years.

ASKAP is part of the Australia Telescope National Facility, which is managed by the Commonwealth Scientific and Industrial Research Organisation. We acknowledge the Wajarri Yamatji people as the traditional owners of the Observatory site.

KEYWORDS ASKAP, surveys, radio-astronomy surveys

Division B

#1040

Enabling Science with Virtual Observatory

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The International Virtual Observatory Alliance (IVOA) was founded in 2002 to enable seamless interoperability of open data and services and to support and foster new areas of research. The IVOA is an international collaboration of 22 nationally-organized VO projects that has developed mature standards that achieve these goals. These standards were in fact in accord with the "FAIR Guiding Principles for scientific data management and stewardship" before they were formally published as such in 2016. VO compliant services now underpin the architectures of all major astronomy archives, and enable data discovery, fusion and access across multiple data sets: they are an enabling technology for science. This presentation highlights several examples of the scientific value of the IVOA: (1) The Gaia archive has been built atop VO protocols since the first release of Gaia data in 2015; there have been over 10 million queries to this archive in to date there have been 2 million queries against this archive; (2) The Australian Skymapper archive has been built from the ground-up on VO-protocols; (3) The NASA archives provide access to data over 15 decades of frequencies through VO-protocols and process one query per second; (4) The IVOA has developed protocols to support planning of multi-messenger astronomy observations through efficient computation of sky regions and their visibility, and to enable discovery of gravitational wave event counterparts by ovelaying probability maps on the sky on all archival electromagnetic data.

KEYWORDS data management, FAIR principles, software

Division B

#858

Satellite interference with radio interferometers – On-sky testing and new mitigation schemes

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We will discuss recent results from a collaboration between the National Radio Astronomy Observatory and SpaceX to explore interactions between radio astronomy interferometers and the Starlink satellite internet constellation. A series of observations assessing the impacts of Starlink ground-based user terminals and the orbiting satellites on the Very Large Array, Very Long Baseline Array and the Green Bank Telescope observations will be described. Real-time coordination of the astronomical/commercial systems and mitigation techniques may offer a path forward for all satellite constellations transmitting near protected radio astronomy bands. A pilot interference-monitoring site has been established in New Mexico to support future studies.

KEYWORDS radio astronomy, radio frequency interference, satellites, interferometers

Division B

#896

The Impact of Satellite Constellation on Optical Astronomy: the Issues and Mitigation Solutions

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Future large constellations of bright satellites in low-Earth orbit (LEOsats) will fundamentally change observational astronomy at optical wavelengths. Nighttime images without satellite trails will no longer be the norm. If the 70,000+ LEOsats proposed are deployed, no combination of mitigations can fully avoid impacts of satellite trails on science programs of ground-based optical astronomical facilities. Astrophotography, amateur astronomy, & the experience of a starry night sky are already affected. The reports from the Satellite Constellations 1 (SATCON1) & the Dark & Quiet Skies for Science & Society (D&QS1) workshops in 2020, support these statements. The aim of SATCON1 & the Satellite Constellation Working Group (WG) of D&QS1 was to better quantify the impacts of LEOsat constellations, explore possible mitigations & make recommendations.

Mitigation strategies for the most damaging impacts on scientific programs are being actively explored by astronomers worldwide & have benefited from collaboration with industry. SpaceX has shown that operators can reduce reflected sunlight through satellite orientation, sun shielding, & surface darkening. A joint effort to obtain higher accuracy public data on predicted locations of satellites could enable some pointing avoidance, & mid-exposure shuttering during satellite passage. Observatories need to adopt more dynamic scheduling & observation management, where effective.

For these reasons, the SATCON2 workshop & D&QS2 conference in 2021 utilized the SATCON1 & D&QS1 recommendations, forming pathways to feasibly employ mitigation solutions for observatories & industry. The SATCON2 Community Engagement WG brought many new voices & perspectives to the issue. Both Policy WGs examined regulatory framework & mitigation approaches from national & international viewpoints. The results laid the foundation for the IAU Center for the Protection of the Dark & Quiet Sky from Satellite Constellation Interference launched in April 2022.

KEYWORDS satellite constellations, observational astronomy, brightness mitigations, trail prediction/mitigations, policy/regulatory frameworks, partnerships with industry, community engagement

Division B

#954

Laboratory Astrophysics – Present and Future

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This presentation, to start the session, will give an overview of the goals and work of commission B5 on Laboratory Astrophysics. In particular the role and work of the two current working groups on "Spectroscopic and Radiative Data for Molecules", and on "Laboratory Astrophysics Data Compilation, Validation and Standardisation: from the Laboratory to FAIR Usage in the Astronomical Community", as well as the recently wound up working group on "High-Accuracy Stellar Spectroscopy", will be briefly discussed. Further, the talk will provide a general introduction to Laboratory Astrophysics activity within the IAU, including plans for future symposia and organisational activities such as the possibility of a Global Network of Laboratory Astrophysics. Concrete and more detailed examples of activity in specific countries and regions to be presented in the following talks of the session.

KEYWORDS Laboratory Astrophysics

Division B
#1868

Laboratory Astrophysics in Korea

Dongsu Ryu[1]

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Laboratory astrophysics is still in its early stages in Korea. Yet, facilities with the potential for laboratory astrophysics have been constructed or are under construction. I will introduce three of them, high-intensity lasers at CoReLS (Center for Relativistic Laser Science), XFEL (X-ray Free Electron Laser) at PAL (Pohang Accelerator Laboratory), and RAON (Rare isotope Accelerator complex for ON-line experiments) at IBS (Institute for Basic Science), and briefly summarize the efforts of laboratory astrophysics with those facilities.

KEYWORDS Laboratory Astrophysics

Division B

#3109

A preliminary survey of Laboratory Astrophysics in South America

Beatriz Barbuy[1]

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South America has several types of activities that could be relevant within the context of Laboratory astrophysics. The presentation will provide information about the different activities, groups and initiatives from South American colleagues. The presentation will be illustrative, but not exhaustive with respect to the topics and/or number of groups.

KEYWORDS

Division B

#1038

Quantum Sensing for Astronomy

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Quantum sensing describes the use of quantum phenomena to perform the measurement of a physical activity or property. Here we highlight two quantum optical techniques in the context of laboratory astrophysics: photon bunching and super resolution.

Photon bunching is the characteristic behaviour of thermal light such as the blackbody radiation emitted by stellar light sources. It is the tendency of thermal photons to propagate closer together than described by the random Poissonian timing distribution, when measured on a very short coherence timescale that is inversely proportional to its spectral width. This photon bunching property when exploited in the spatial domain, allows for long-baseline spatial intensity interferometry approaching the micro-arcsecond angular resolution required to image stellar surfaces or exoplanets.

Temporal photon bunching behaviour may correspondingly be applied towards correlation spectroscopy to resolve very narrow linewidths. Its ability to measure temporal coherence may also be used to detect for evidence of phase dispersion over cosmic distances, e.g. test for signatures of Lorentz Invariance Violation. This may also be useful in the search for astrophysical lasers, be it natural candidates such as the Eta Carinae system and Wolf-Rayet stars, or from technosignature candidates by the Breakthrough Listen programme.

Super resolution refers to the extraction of information beyond the diffraction limit of the collection optics aperture. One such technique is based on separating the common radially symmetric mode from the asymmetric modes of input light, and thus separate their respective shot noise contributions into different detectors. In the astrophysical context, this may be useful to enhance luminosity transit measurements by separating the exoplanet transit signal into a different detection channel from the main source of shot noise contribution by the host star, and therefore potentially increase the signal-to-noise ratio.

KEYWORDS quantum sensing, photon bunching, intensity interferometry, g2, hanbury-brown and twiss, image inversion, super resolution

Division B

#1077

Activities of laboratory astrophysics in Japan

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I report the activities of laboratory astrophysics (astrochemistry) in Japan. The relevant society in Japan is gradually spreading in the last decade. Thank to recent big projects, astrophysics and astrochemistry have been recognized as interesting interdisciplinary science among pure physicists and chemists. At the same time, technical developments enable us to investigate various elementary processes in both gas and solid phases, which used to be hardly performed. Interaction among researchers in laboratory astrophysics, astronomy, planetary science, physics, and chemistry is getting stronger. However, unfortunately, the number of researchers in laboratory astrophysics is still limited.

KEYWORDS laboratory astrophysics, laboratory astrochemistry, society in Japan

Laboratory Astrophysics in the US

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Laboratory astrophysics is a strong and vibrant field in the US with its primary national representation as a full Division of the American Astronomical Society (AAS). Laboratory Astrophysics is also represented in other major scientific societies such as the Astrochemistry subdivision of the American Chemical Society (ACS), the High Energy Density Laboratory Astrophysics (HEDLA) and the Division of Astrophysics (DAP) of the American Physical Society (APS) to cite a few. Laboratory Astrophysics and Astrochemistry is also well represented in federal agencies such as the National Aeronautics and Space Administration (NASA) and the National Science Foundation (NSF) where research programs are fully dedicated to the support of laboratory astrophysics research. Laboratory Astrophysics is also well represented in the Academic arena where Physics, Astronomy and/or Chemistry Departments in many universities host a laboratory Astrophysics or Astrochemistry curriculum. The increasing recognition of the field of laboratory astrophysics has been recently reinforced by its inclusion into the recommendations of the two most recent Decadal Surveys of the National Academy of Sciences (NAS). I will discuss and present the many aspects and representations of Laboratory Astrophysics in the US and summarize the current efforts in the field.

KEYWORDS

Division B

#3468

Laboratory Astrophysics in Europe

Paul Barklem[1], Marie Lise Dubernet[2]

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[2]*LERMA, Observatory of Paris, PSL research University, France*

Europe has a broad activity in Laboratory Astrophysics, covering theory and experiment, as well initiatives promoting open science, including databases and tools aiding connection to astrophysical modelling and interpretation of observations. The talk will present some examples of Laboratory Astrophysics in Europe, as well as examples of organisation of such activities at national and European levels encouraging interaction between astrophysicists, physicists, and chemists.

KEYWORDS

Division B
#1492

The Global VLBI Alliance

Francisco Colomer[1]

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By its very nature, VLBI has always depended on international collaborations. These have led to the formation of several formal VLBI networks, which in turn regularly form combined arrays. In astronomy, "global VLBI" is the term often used for the coordinated observations of the European VLBI Network (EVN) and the Very Long Baseline Array (VLBA). In the past, the "Global VLBI Working Group" (GVWG) worked as an umbrella for the space VLBI and ground VLBI network collaboration (VSOP), organizing the logistics (time allocation of ground network resources was agreed in the GVWG) and technical compatibility. Nowadays, as several independent VLBI networks and instruments exist, we recover that spirit, by the establishment of a Global VLBI Alliance (GVA).

The GVA facilitates the flow of information between VLBI networks, including sharing strategies, technical developments for compatibility, logistics, operations, and user support. It also promotes, proposes and coordinates common observational campaigns with these existing networks. Moreover, with the advent of the Square Kilometer Array (SKA) and its precursors, such global coordination of the various networks and their participating telescopes will be required. The Next Generation Very Large Array (ngVLA) may also collaborate with a global VLBI array. In such scenario, the GVA will serve as contact point and framework of collaboration of the VLBI networks and these other facilities. Additionally, it can encourage and support new VLBI activities (like the African VLBI Network - AVN, Iniciativa VLBI IberoAmericana - IVIA, developments in India and southeast Asian countries, etc.).

The GVA will also facilitate that adequate information is provided to the users. For this, a unique common portal will explain the characteristics of the different networks, and the options for users to access them or in combination.

GVA web: http://www.gvlbi.org/
GVA twitter: https://twitter.com/GlobalVlbi

KEYWORDS VLBI, Radio astronomy, networks, SKA, multimessenger

Division B

#2314

From the VLBA to the ngVLA

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The Very Long Baseline Array has been a leader in high-resolution radio interferometry since its inception almost 30 years ago with significant scientific impact in many research areas. It has stayed at the forefront of research facilities through a series of upgrades of the antennas, the correlator, and post-processing software. These upgrades are continuing with an ongoing upgrade to the digital back-end systems and with the possibility of new and/or improved receivers and calibration infrastructure on the horizon.

On longer timescales, the next generation Very Large Array (ngVLA) will be deployed, superseding the capabilities of both the VLA and the VLBA, merging them into a single, real-time instrument. I will present the performance parameters of ngVA in long baseline use cases and will describe some new modes of operation that it will offer.

KEYWORDS VLBI, VLBA, ngVLA, Interferometry, Digital

Division B

#711

The East Asian VLBI network

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The East Asian VLBI network has been in regular operation since 2010 and conducts 1000 hours of open-use observations per year. Currently, a total of 16 VLBI stations (4 in China, 8 in Japan and 4 in Korea) participate in the network, and correlation processing is mainly carried out by the Daejeon (Korea) correlation station and partly by the Mizusawa (Japan) and Shanghai (China) correlation stations. Detail is shown in https://radio.kasi.re.kr/eavn/about_eavn.php. The maximum baseline length of EAVN is 5,200 km and the minimum baseline length is 100 km. Observation frequencies are in the C/K/Q bands with a nominal recording rate of 1 Gbps, and some stations offer phase-compensated observation using fast switching and two-beam observation, simultaneous K/Q observation and wide-field observation modes. Polarization and 2/4 Gbps wide-field observations are currently being tested.

We have discussed science cases and operation issues in the directors' meeting of EAVN. Many EAVN stations have already joined the EVN, and some Chinese stations are conducting joint observations with the VLBA, so further discussions are expected. We would like to move forward the Global VLBI Alliance.

KEYWORDS VLBI, East Asia

Division B

#1396

The southern hemisphere Long Baseline Array

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The southern hemisphere Long Baseline Array (LBA) involves a network of telescopes spanning Australia and extending to New Zealand and South Africa. The LBA observes routinely at frequencies between 1 and 22 GHz, with some telescopes having 7mm and 3mm capabilities also. In recent years, LBA science has included studies of jet motions in AGN, maser outbursts, parallaxes and proper motions of galactic objects, and southern hemisphere calibrator surveys. CSIRO is presently reviewing the science case for the LBA in the SKA era, and is developing a prototype based on MWA dipoles for a low frequency VLBI array called LAMBDA (Low-frequency Australian Megametre Baseline Demonstrator Array). These activities will be reviewed in this presentation.

KEYWORDS VLBI

Division B

#1132

SKA-VLBI Capabilities and Science Cases

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In the SKA era, Very Long Baseline Interferometry (VLBI) networks will continue to provide high angular resolution images of the sky which will be important for the realisation of many of the SKA science cases. These cases include pulsar, maser and AGN astrometry; AGN and jet physics; scintellometry and a wide range of transient phenomena such as X-ray Binaries, Gamma Ray Bursts, Tidal Disruption Events and Extreme Scattering Events.

For SKA phase 1, high angular resolution will be achieved by combining either the phased SKA1-MID or SKA1-LOW cores with existing (or developing) VLBI networks across the globe. The European VLBI Network, Long Baseline Array, nascent African VLBI Network and other emerging VLBI telescopes will effectively provide the high resolution arms of the SKA. This array will have previously unrivalled sensitivity over most of the sky.

Astrometric precision of 10 microarcseconds should be more or less routine with SKA-VLBI at cm wavelengths, with 1 microarcsecond precision attainable.
However, the ability to take full advantage of this depends on a number of technical issues including, but not limited to: astrometric calibration, understanding the positional stability of the faint radio sources, understanding the effects of interstellar scattering, observational flexibility, multi-beam capabilities of both the SKA core and other sensitive telescopes in the array, the availability of telescopes in strategic locations and the development of suitable calibration software.

Significant progress has been made by the H2020 JUMPING JIVE project to ncorporate the VLBI observing mode into the SKA and the recent symposium "VLBI in the SKA Era" demonstrated the wide ranging scientific interest.

We will provide an overview of the technical capabilities of the SKA-VLBI network and the planned science cases for SKA-VLBI, with a brief forward look to the necessary technical developments required to unleash the full potential of the SKA-VLBI network.

KEYWORDS Radio Astronomy, VLBI, New Facilities

Division B

#762

Laboratory Astrophysics Databases: from the provider to the user: encouraging FAIRness

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This presentation, to start the session, will give an overview of the goals and work of the inter-commission B2-B5 working group "Laboratory Astrophysics Data Compilation, Validation and Standardization : from the Laboratory to FAIR usage in the Astronomical Community" that was created in November 2021. It will provide an introduction for the session's talks, which will present some concrete examples in different communities. Through a general discussion at the end of the session, several key points will be addressed including the different models that can be envisaged for organization at the international level, and how an efficient and robust workflow for between data producers and data users can be achieved.

KEYWORDS Database, Atoms, Molecules, FAIR, Codes, Tools

Division B
#1042

FAIR principles in IVOA

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This paper describes how implementation of data discovery and access services that comply with Virtual Observatory (VO) standards also provide compliance with the "FAIR Guiding Principles for scientific data management and stewardship", published in 2016. The VO standards are developed by the International Virtual Observatory Alliance (IVOA; http://ivoa.net)), an international collaboration of 22 nationally-organized VO projects. The IVOA was founded in 2002 to foster discovery of, and access to worldwide astronomy databases through a common set of interfaces. The goal of the IVOA from the outset was to enable seamless interoperability of open data and services; as such it was implementing what became know as FAIR principles before they were formalized.

The IVOA has by now developed of a mature set of standards, and VO compliant services underpin the architectures of all major astronomy archives. Generally, IVOA standards published make data almost FAIR: of the 15 items in the breakdown of the four major FAIR principles, IVOA standards meet all but four of them (though the most recent standards, such as the VO data model, do not yet have universal deployment). The four non-compliant items are in areas that are considered out of scope for the IVOA. An example is licensing, which is left for data providers. Among the IVOA standards, the Simple Line Access Protocol (SLAP) deals with spectroscopic line lists. One of the main goals is to allow astronomers to discover, through the Virtual Observatory, archived spectra and to easily identify the observed absorption and emission lines in the spectra by queries in line list databases. SLAP was introduced at the IVOA in 2010. A more modern access protocol, with better integration in the IVOA standards, is being developed thanks to, among others, VAMDC (Virtual Atomic & Molecular Data Center) developers.

KEYWORDS FAIR principles, data management, software

Division B

#436

The NASA Ames PAH IR Spectroscopic Database

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Polycyclic aromatic hydrocarbons (PAHs) permeate the Cosmos. PAHs are an extremely robust class of chicken wire-shaped molecules made up of carbon and decorated by hydrogen at their periphery. Their distinct infrared (IR) signature is observed from solar system objects, interstellar medium sources, galaxies as a whole, and even beyond galaxies.

The astronomical PAH spectrum consists of strong bands and weaker features perched on top of broad plateaus. The available spectroscopic detail reveals key information on the make-up of the underlying PAH population, which is sensitive to local astrophysics conditions. However, PAHs don't only witness their environment but also actively participate in controlling it. Therefore, PAHs are excellent for probing astrophysical and astrochemical conditions.

The NASA Ames PAH IR Spectroscopic Database (PAHdb; www.astrochemistry.org/pahdb/) is a web-accessible database with accompanying models and tools to readily analyze and interpret astronomical PAH observations. PAHdb contains the world's foremost collection of genuine laboratory-measured and quantum-chemically computed spectra from over 4,000 PAHs and PAH clusters. These can be used, among other, to extend the traditional PAH band strength analysis to readily quantify the PAH charge state, size distribution, etc. through a database-fitting approach.

PAHdb models and software tools are implemented in both IDL and Python and can be obtained from GitHub (github.com/pahdb/). Furthermore, information and comprehensive manuals describing the data, models and software can be found via the PAHdb Documentation Portal (pahdb.github.io). Taken together, this makes PAH spectroscopic data findable, accessible, interoperable, and reusable (FAIR), which will become extremely important when the high-fidelity spectral data from the James Webb Space Telescope (JWST) starts coming in. JWST is set to revolutionize IR (PAH) astronomy and many, if not most, of its observations will contain signs of PAHs.

KEYWORDS PAHs, Databases, Spectroscopy, Laboratory Astrophysics, IR Astronomy

Division B

#2188

Laboratory Astrophysics Databases on Grains and Ices: From the Laboratory to the Users

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Interstellar dust and ice play a major role in the thermodynamical and chemical evolution of the interstellar medium (ISM), protoplanetary and planetary disks, and planets. Dust including non-refractory ices and refractory dust grains absorb and scatter stellar light and can reemit the absorbed energy from infrared to millimeter wavelengths. In addition, it influences the formation rate of H2 and many other complex organic molecules being formed either on bare surfaces or in molecular ices on top of grains. Previous and recent IR observations with the observatories ISO, Spitzer, Herschel, and now JWST provided and will provide a wealth of new spectroscopic data, characterizing solid dust and ice components in various environments. The analysis of observed spectral features delivers important information on grain sizes, composition, and structure as well as temperature and spatial distribution of the material. For the interpretation of observations and the modelling of important astrophysical processes such as disk and planet formation, the spectral properties of dust and ice in a broad wavelength range are required. The relevant spectral data for interstellar, circumstellar, and protoplanetary grains and ices at different levels of photon-, ion-, thermal-, and collisional-induced modifications can be obtained by measurements of cosmic dust and ice analogs in the laboratory. An understanding of both macro- and micro-physical properties of the dust and ice and how these properties evolve with the environment is indispensable. Databases of dust and ice materials are required to offer not only the spectral data, but also important information on the specific properties of the materials and measurement procedures. The current state of databases of optical constants or absorption data of solids containing information on the samples and references to relevant papers as well as information to the measurements or calculations will be discussed.

KEYWORDS dust, ice, interstellar medium

Division B

#2715

About the atomic and molecular databases in the planetary community

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Atomic and molecular data play a key role in the understanding of the physics and chemistry of processes in several research topics, including planetary science and interdisciplinary research in particular the atmospheres of planets and planetary explorations, etc. Databases, compilation of spectroscopic parameters, and facility tools are used by computer codes to interpret spectroscopic observations and simulate them. In this talk I will present existing atomic and molecular databases of interest to the planetary science community focusing on access organization, databases infrastructures, limitations and issues, creation and maintenance, etc.

KEYWORDS Atomic and molecular data, Planetary atmospheres

Division B

#813

ENIIGMA:
A Python package for ice spectral decomposition of protostars

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In the cold regions of protostars, atoms and molecules in the gas phase can stick on dust grains and form the so-called ice mantle. Understanding the chemical composition of the mantle and its diversity from source to source requires a systematic comparison with laboratory-measured ice spectra. In fact, telescope observations analyzed in light of experimental data have allowed concluding that H2O[1,2] ice is the major component of the interstellar ices and also that molecules can be mixed in ices (e.g., CO:CH3OH[3]). Much more information about the composition, morphology and structure of interstellar and circumstellar ices will be obtained in the next decades with the James Webb Space Telescope and the ground-based Extremely Large Telescope. While a large variety of laboratory data is needed to interpret these observations, the question that remains is which data best fit the observations. Previous works[4,5] report high degeneracy in the fits of astronomical observations with ice spectra. In this context, we created the ENIIGMA fitting tool[6], which is a public Python package to search for the global minimum solution by combining laboratory-measured ice spectra. The code handles a large amount of laboratory-measured ice spectra and uses genetic modelling algorithms to fit astronomical data. The solutions are assessed using two-dimensional $\chi 2$ maps, recurrence plots and histogram analysis. This statistical analysis allows us to quantify the degeneracy of the solutions and to derive robust ice column densities. By using ENIIGMA, we have fitted the broad-band spectrum of the protostar Elias 29 between 2.5 and 20 µm. We have derived the ice column densities for the major ice components, and we have found evidence for the presence of ethanol (CH3CH2OH) in the ices.

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KEYWORDS astrochemistry, ices, infrared spectroscopy, protostars

Division B

#2050

The IAU system for UV photometry

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The charter of the UV Astronomy WG during the triennium 2018-2021 was to set the grounds for the definition of a UV photometric system suitable to be implemented in small missions and that grows on the scientific challenges addressed by using UV astronomical observations. The recommendations gathered in the IAU Resolution B4 “On the use of a standard photometric system in ultraviolet (UV) astronomy” was the end result. In this talk, the methods foreseen for the implementation of the resolution will be presented and the needs for further calibration sources will be described.

KEYWORDS UV Astronomy, UV Photometry, Space Astronomy

Division B
#2999

The Ultraviolet Spectrograph on Juno: UV-calibration and stellar UV-science possibilities.

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The Juno mission is a NASA New Frontiers mission, placed in a polar orbit around Jupiter since July 2016. The Ultraviolet Spectrograph onboard Juno (Juno-UVS) is a photon-counting imaging spectrograph, designed to cover the 68-210 nm spectral range, which includes the H2 Lyman and Werner bands of Jupiter's auroras. Because of the 2-rpm spin of Juno, UVS nominally observes 7.5°x360° swaths of the sky during each spin of the spacecraft. The spatial resolutions along the slit and across the slit, i.e., in the spin direction, are respectively 0.16° and 0.2°, while the filled-slit spectral resolution is ~1.3 nm. UVS also possesses a scan mirror which allows, when combined with Juno's spin, to access half of the sky at any given moment. During Juno's prime mission (July 2016- July 2021), over 99% of the sky has been observed by UVS, and more than 25,000 spectra of O, A, and B spectral-type stars in the 0-7 V-magnitude range been extracted to date, over a sample of ~500 individual stars. Selected stars among this list are used to calibrate the UVS instrument. This talk describes how previous spectral databases from the International Ultraviolet Explorer and the Hubble Space Telescope have been used for UVS's calibration purposes, and present the stellar UV-science capabilities offered by UVS's unique spectral atlas coverage in the 68-115 nm range with repeated temporal information.

KEYWORDS

Division B

#3238

Swift/UVOT photometric standards

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The Ultraviolet-Optical Telescope aboard the Neil Gehrels Swift Observatory has been in orbit since 2004. The instrument has a 30-cm mirror and a microchannel plate intensified CCD. Data are taken through three near-ultraviolet (NUV) filters and UV grism. The photometric calibration of UVOT in the NUV filters is based on faint white dwarf stars, with later-type stars included to constrain the contribution of the red leak. Hot white dwarfs are exceptional objects to use for UV calibration since they can be culled from large databases, are photometrically stable, have copious UV emission and they are relatively straight-forward systems to simulate spectral-energy distributions for. Regular observations of white dwarf standards have been used to monitor the decline in sensitivity of the instrument, which has generally been about 1.5% a year but shown some leveling off in recent years. Models of large-scale sensitivity are applied to post-processing photometric measures to produce accurate photometry across the face of the CCD. Regular monitoring has also revealed the existence of "dark patches" on the CCD, where the sensitivity drops by a few percent to a couple of tens of a percent. We have combined Swift, GALEX and ground-based optical data to produce a system of faint UV standards that paves the way for calibration of future instruments.

KEYWORDS ultraviolet, standard stars, photometry, swift

e-Posters

Division B

#3401

Designing of 'Tool Influence Function (TIF) Prediction Model' for Orthogonal Velocity Field Tool (OVT)

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The main purpose of this research is to analyze the TIF (Tool Influence Function) data generated from the Orthogonal Velocity field Tool (OVT). The OVT machine is used for polishing SiC materials which in turn create highly polished segmented mirrors. These mirrors become an integral part of the SiC telescope system.

Physically collecting the TIF polishing data and analyzing it is a cumbersome and time-consuming process. Here, TIF data analysis is a multi-layered analysis of how the material is polished against the variables (controllable, semi-controllable, and uncontrollable) of the OVT tool.

Accurately predicting and achieving the TIF value against the particular set of variables [Force(F), Velocity (V), Time (T)] suggested by Preston's Equation is the key challenge in obtaining highly polished SiC mirror surfaces.

Through this poster, our main objectives are,
1) To showcase the techniques of machine learning applied to analyze the TIF data.
2) To represent the research framework to develop the TIF prediction model.
3) To give insights into the evolutionary process of the prediction model building and future challenges, and scopes for improvements.

KEYWORDS Tool Influence Function (TIF), Orthogonal Velocity Field Tool (OVT), Preston Equation, Predictive Model, Regression Method, Regression Weight, Error Correction

Division B

#3366

Simulation of an off-axis freeform three-mirror system for observation of low surface brightness universe using Photon Simulator (PhoSim)

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We introduce our new instrument developed for low surface brightness (LSB) science, the KASI-Deep Rolling Imaging Fast-optics Telescope (K-DRIFT) pathfinder, and present the preliminary result of photon simulations of its performance. For the study of the LSB structures, we need to optimize the observing instrument, the observation strategy, and the data reduction technique. In particular, understanding and minimizing the systematic errors caused by imperfect flat-fielding, sky over- /under-subtraction, point-spread function (PSF) wings are all crucial, since they decide the robustness of the detection of LSB structures. Based on our knowledge of the LSB studies, we attempt to overcome the possible systematics through a special optical system. In this study, we utilized a photon simulator (PhoSim) to realize the special optical design of the new telescope, a linear-astigmatism-free three-mirror system (LAF-TMS), and simulate the expected final image. Considering the general optical design, the off-axis structure, the free-form surfaces, and additional adjustments, we could produce a realization of the full optics of the K-DRIFT pathfinder. We realized the off-axis and freeform optics in the PhoSim system with success, which resulted (without considering atmospheric effect) in a full-width half-maximum (FWHM) as predicted by optical design. The optics and PhoSim realization of the K-DRIFT pathfinder will be accessible to the public via https://bitbucket.org/phosim/phosim_release.

KEYWORDS instrumentation: telescopes, wide-field small optical telescope, image simulation, observation: low surface brightness

Division B
#3278

A new method for extracting gravitational wave: Black-hole ringdown mode search using Auto-Regressive method

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The ring-down part of gravitational waves in the final stage of merger of compact objects tells us the nature of strong gravity which can be used for testing the theories of gravity. The ring-down wave, however, fades out in a very short time with a few cycles, and hence it is challenging for gravitational wave data analysis to extract the ringdown frequency and its damping time scale. We develop a new method, the autoregressive modeling (AR) approach, which extracts waveform by fitting a linear function from bare data. It works well for small number of data points, and does not require any templates. After obtaining the best parameters using mockdata, we applied this method for black-hole merger events of the LIGO/Virgo/KAGRA O3 catalog (GWTC-3). We find that for high SNR events, we can extract ring-down waves properly. The identified ringdown modes are around those reported in GWTC-3, i.e. no significant deviations from the modes predicted by general relativity. This method should work for extracting higher modes of ring-down waves, but we do not find them yet.

KEYWORDS Gravitational Wave, Black Hole, Data Analysis, New Method

Division B

#3138

Development of the wide IF 230 GHz SIS mixer design for KVN-Pyeongchang VLBI station

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The 230 GHz SIS mixer is designed for the new KVN station located in Pyeongchang, Korea. The new station is targeted to show a good performance in wide IF bandwidth within the RF band from 211 to 275 GHz and the probe and the mixer chip is optimized to full fill the aim. The probe is based on the waveguide and the output impedance of the probe shows a tear-drop shape which shows a small variance within the RF range. Various structures are added such as Tuning steps near the probe for the wideband match. The mixer used 3 series-connected junctions and the matching circuits are designed with two different methods of tuning. Type A used transmission lines between the probe and the junction array to match the junction embedding impedance to the optimum source impedance. Type B used junctions as a tuning element in transmission lines to replace the highly capacitive strip lines resulting in low total capacitance of the circuit. Both designs used identical RF choke which is composed of multiple quarter-wave transformers. The capacitance of the whole circuits, which is required to be reduced to have a wide IF bandwidth, is 150 fF and 160 fF for each design and these numbers are definitely lower than the existing 230GHz SIS mixers. The performance of the mixer is tested using Supermix, which performs full harmonic balance and small-signal analysis calculations of the SIS receiver based on Tucker's quantum mixer superconducting theory. Over the whole RF band, both two designs show a small gain variance below 1dB and a flat trace of the mixer noise temperature within IF frequency 1 to 16 GHz.

KEYWORDS receiver, SIS mixer, THz

Division B

#3091

CARTA: Visualization with the 'Cube Analysis and Rendering Tool for Astronomy’

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CARTA is a new, high performance visualization tool for astronomy, in particularly multi-dimensional, large radio image cubes. CARTA is built as a server-client structure that allows viewing images that are stored remotely or locally in a local browser window. Its parallelized architecture includes GPU accelerated and tiled rendering, memory-efficient image and progressive spectrum loading. TB sizes cubes can be loaded in seconds. Version 3 of CARTA will be available this summer 2022. It has a multitude of newly developed features, such as position-velocity diagrams, moment maps, vector field overlays, image arithmetics, complex image display, 2D Gaussian fitting, polyline profiling, and multi-paneling. CARTA is developed to replace the CASAviewer and to display images from SKA precursors and the future ngVLA. CARTA is also integrated in the ALMA and NRAO archives as an interactive image viewer of archival maps. Basic python scripting is also included in CARTA v3, but is still under active development. CARTA partners are ASIAA, IDIA, NRAO, and the University of Alberta.

KEYWORDS data visualization, software

Division B

#2042

Construction of 8 inch Dobsonian telescope

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A Newtonian telescope was built to show students celestial objects through the telescope. The optical tube which holds primary mirror assembly, secondary mirror assembly and focuser was made by a rolling sheet metal. A primary mirror with the diameter of 8-inch(200 mm), f/5 was purchased. A mirror support was made by wooden material and clipped by 3D printed clippers to the mirror. A 3D printer was also manufactured in-house to produce several parts of the telescope. The support of the secondary mirror was also made by 3D printing and glued to the secondary mirror. Several eyepieces were prepared ranging from 9 mm to 30 mm, which give the magnification of 110 ~ 33.

A Dobsonian mount was made by an wooden material. To move the telescope to altitude and azimuth directions, truths bearings were adopted. 3D printed parts were used to attach the bearings to the optical tube, and an U-shaped bearing house was also made by 3D printing.

The telescope showed beautiful images of the Moon, planets and stars. This work gave us great experiences in telescope making. It is simple, easy and inexpensive to build a Dobsonian Newton telescope and to operate it manually. We hope to make this kind of telescope more and more, so that we can distribute them to many schools. In this paper, manufacturing procedures of the telescope and the 3D printer are described and images of the Moon through the telescope are shown.

KEYWORDS Telescope, Newtonian telescope, Dobsonian mount, 3D printing

Division B
#1372

Deep learning proves to be an effective tool for detecting previously undiscovered exoplanets in Kepler data

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Using deep learning with the Adam optimization algorithm in this research, I detected 11 previously undiscovered exoplanets in the Kepler data. Although some of the exoplanet transit signals were evident, others were not as strong and need further evaluation. By using my own code, open source libraries, and deep learning packages such as TensorFlow and implementing the Adam algorithm as an optimizer, I developed a Python program for exoplanet detection. The program first normalizes the transit light curves, trains the deep learning model using the Adam optimizer, folds the transit light curves to intensify the transit signals, then uses the model to search for exoplanet transits in the Kepler light curves. Among the newly detected exoplanets, 9 of them are ultra-short period (USP) exoplanets with orbital periods shorter than a day, and the 2 others are short period exoplanets with periods between 1 to 10 days. Because the Kepler mission lasted for nine years and observed each star for a selected period of time, there are much more Kepler Objects of Interest (KOI) with shorter periods than those with long periods in the NASA database. This may be a reason why the orbital periods of the detected exoplanets in this study are shorter than 10 days. Meanwhile, the detection of these new exoplanets, especially the USP exoplanets, can shed light on their kind and expand our views on their planetary systems, which possess different features than our Solar System. Finally, these findings show that artificial intelligence such as deep learning can be an effective technological tool to detect objects of interest in astronomy big data.

KEYWORDS exoplanet discovery, Kepler, deep learning, TensorFlow, big data, ultra-short period exoplanet, short period exoplanet

e-Talks

Division B

#3416

Kinetics and Product Measurements for Reactions of Astrochemical Relevance Involving CN Radicals

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Studying the different possible reactions and their dynamics under the low–temperature conditions of the interstellar medium and various planetary atmospheres is essential to understand the chemical evolution of various species detected in these environments. CN radical is ubiquitous in space but the kinetics measurements of reactions of CN, especially at low temperatures, still remain scarce.

Here, I will show our work on low–temperature laboratory studies to explore CN reactions performed using the CRESU technique (French acronym for Reaction kinetics in uniform supersonic flow) coupled with pulsed laser photolysis–laser induced fluorescence and chirped–pulse Fourier transform microwave spectroscopy. A new E–band chirped pulse FT–microwave spectrometer has recently been developed and integrated with the CRESU technique. The technique was applied to investigate product channel–specific branching ratios and I will discuss the progress for the same.

KEYWORDS Low-temperature, Reaction kinetics, Branching ratio, Chirped-pulse microwave spectroscopy, Radicals

Astronomy for All
Busan 2022

Division B

#3400

Development of the optics for the Athena x-ray telescope

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Athena is the European Space Agency's next flagship telescope, scheduled for launch in the 2030s. Its 2.5-m diameter mirror will be segmented and comprise more than 600 individual Silicon Pore Optics (SPO) grazing-angle imagers, called mirror modules. Arranged in concentric annuli and following a Wolter-Schwartzschild design, the mirror modules are made of several tens of primary-secondary mirror pairs, each mirror made of silicon, coated to increase the collective area of the system, and shaped to bring the incoming photons to a common focus 12 m away. The mission aims to deliver a Half-energy width of five arc-seconds and an effective area of about 1.4 m2 at 1 keV.

Ahead of important programmatic milestones for Athena, we present the status of the optics technology, and illustrate not only recent x-ray results but also the progress made on the environmental testing, manufacturing and assembly aspects of the optics.

KEYWORDS SPO, Athena, telescope, x-ray, Wolter-Schwartzschild, silicon

Division B

#2903

The Dynamic REd All-sky Monitoring Survey (DREAMS)

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The DREAMS telescope is a near infrared survey telescope currently under commissioning at the Siding Spring Observatory in Australia. Equipped with a 4 sq.deg field of view, the 50cm telescope will scan the sky in the H and J bands with a depth of 17.9M and a cadence of approximately a week. This presentation will focus on the technical details of the telescope, its operation and the research that will benefit from the survey. This new facility will provide the basis for a “Transient factory” in the southern hemisphere and complement the capabilities of the LIGO and VRO observatories.

KEYWORDS Survey, Infrared, Transient, Time Domain

Astronomy for All
Busan 2022

Division B

#2676

Defining the Concept of Polishing Quality for Precision Optical Surfaces and Finding Out Various Control Factors Affecting its Material Removal Characteristics

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To gain comprehensive understanding and controllability of precision optical polishing, and figuring the process which have been regarded as a 'black art' is one of the goals of persuasion for the optics fabrication community. As achieving the full degree of controllability over the optical fabrication process is almost not possible, defining the sound concept of polishing quality for precision optical surfaces becomes challenging. In order to perform the precision polishing of segmented mirrors and to check whether the degree of polishing is within acceptable range (good to worse), it is necessary to be able to evaluate the polishing quality.

The present research focuses on two objectives,

(1) To define the concept of polishing quality for precision optical surfaces

(2) To determine the wide-ranging polishing and figuring control factors (controllable, semi-controllable, non-controllable) and disturbance variables which are deficiently understood and ill reported with sufficient details.

This research attempts to evaluate the quality of polishing, the concept was defined and criteria for evaluation were prepared. Regression analysis was performed using the data obtained with TIF depth, and the relationship between the influencing factors such as p, v, and t and the polishing quality was identified. By Preston equation, TIF depth has a proportional relationship with p, v, and t, and the larger the TIF depth value, the better the polishing quality. After data analysis, the term polishing quality was defined through the results, and a method of predicting data was devised to improve polishing quality.

Furthermore, the authors have described, the polishing process from a systems point of view (dealing with complex systems), the Orthogonal Velocity field Tool (OVT) machine, the experiments conducted, the data analysis program, and the results are reported towards defining and measuring polishing quality. A new evolutionary system thinking model has been developed for the future development of precision optical polishing process as a quantitatively controllable engineering process.

KEYWORDS Precision Optical Polishing, Polishing Quality, Polishing Factors, TIF depth, Preston Equation, Regression Analysis, Orthogonal Velocity field Tool (OVT)

Division B

#2610

Topological features of sliding window embeddings for signal detection

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Persistent homology of sliding window embeddings has been shown to be a useful feature extraction tool in time series classification. Convolutional neural networks, which have become famous for their high efficacy when dealing with image data inputs, have also seen some appreciation for their performance on time series analysis problems including signal detection and classification. Due to the nature of the convolution layers, it can be effective to naively combine normalized raw input with features extracted by explicit processes such as TDA. This has turned out to be effective as a synergistic combination for difficult signal detection and classification problems, such as the detection of gravitational wave signatures in interferometer readings.

KEYWORDS TDA, classification, homology, CNN, signal, detection, time series

Astronomy for All
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Division B

#2344

A Novel Method for Image Improvement and Restoration in Optical Time Series

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Globular clusters (GCs) are considered strong candidates for hosting free-floating planets (FFPs). Since they are not bound to a star, FFPs are undetectable by any traditional searching methods, transit, or radial velocity. Gravitational microlensing, which causes transient brightening of background stars by passing foreground masses, is an established tool for detecting extrasolar planets. Moreover, it is the only way to detect the population of FFPs in GCs as their direct imaging is not possible due to large distances. By employing the image subtraction technique, differential photometry on the time-series images of GCs could be used to build light curves, extract variability events, and inspect them for the presence of microlensing. However, instrumental anomalies and varying observational conditions distort the Point Spread Function (PSF) of stars, affecting the subtraction process's quality, leading to false-positive transient detection and large-scale noise structure in the subtracted images. We propose an iterative image restoration method, called the Flux Conserving Scaled Gradient Projection (FC-SGP), that successfully restores the shapes of stars while preserving their flux well within the photometrically accepted tolerance. We validate FC-SGP using physically motivated metrics like FWHM, radial profile, and star centroid error. We also compare the proposed method with the famous Richardson-Lucy (RL) deconvolution algorithm and the original SGP algorithm and show that FC-SGP is more efficient for restoring point-like objects like stars. An optional validation step finds the optimal set of FC-SGP parameters based on pre-defined criteria. We employ parallel computing and caching to speed up the process for efficient restoration of the whole field in our GC time-series dataset.

KEYWORDS Mathematical Optimization, Image Restoration, Image Subtraction, Globular Cluster

Division B

#2019

Science with the CCAT-prime Observatory: From Galactic Star Formation to the Edge of the Universe

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The CCAT-prime collaboration are currently constructing the Fred Young Submillimeter Telescope (FYST), a wide-field, 6-m aperture telescope to be located sited at more than 5600 meters elevation on Cerro Chajnantor in northern Chile. The facility will host two first-light instruments covering the 350 micron to 2 millimeter wavelength range spectroscopically and via broad-band polarimetric imaging at a mapping speed that is over ten times greater than existing and near-term facilities. These capabilities will be critical to address important astrophysical questions ranging from Big Bang cosmology through reionization and the formation of the first galaxies to star formation within our own Milky Way galaxy. We will highlight some of the key science areas enabled by this system and the envisioned survey strategies, leading to key advances in our understanding of the role of large-scale interstellar medium kinematic structure and excitation in the star formation process on (sub-)parsec scales, and a tomographic view of the star-forming galaxies driving Cosmic Reionization on megaparsec scales.

KEYWORDS submillimeter, cosmology: observations, galaxies: evolution, instrumentation: spectrographs, ISM: kinematics and dynamics, surveys, telescopes

Astronomy for All
Busan 2022

Division B

#1491

GROWTH-India Telescope: A Robotic Eye for Time Domain Astronomy

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The GROWTH-India telescope (GIT) is a fully autonomous telescope dedicated to the time-domain astronomy. The telescope is situated at the Indian astronomical observatory (IAO), Hanle, 4500 m above sea level and is operated jointly by IIT Bombay and IIA Bengaluru. This 0.7m telescope is accompanied by a 4K CCD camera with a 0.5 sq. deg field of view, making it suitable for the study of optical counterparts to gravitational wave (GW) events, and gamma-ray burst (GRB) afterglows. I present the automation of the observing scheduler and data processing pipeline of the GIT. The observing operation, as well as data reduction of GIT, are completetly autonomous. The fully automated data reduction pipeline can perform tasks like data download, data reduction, transient search with its newly built image subtraction, and transient search with ~94% efficiency. This pipeline is further supported with a few helper slack bots that can trigger the telescope for GRB events and other Target of Opportunity observations (ToOs). The telescope does preliminary error handling on its own and notifies the core team with a phone call if a severe quality error occurs during observations. The telescope and pipeline can observe and perform data reduction automatically for sidereal and non-sidereal targets. This facility has contributed significantly to a variety of science cases, including the follow-up of GW events during O3, rapid follow-up of fast transients like GRB optical afterglows, SNe, observations of near-earth objects, etc. To date, GIT has published a handful of scientific studies for the mentioned fields in form of 10 refereed papers, over 150 GCNs & ATels, and MPECs, thanks to its high-efficiency observing operations and standardized data products.

KEYWORDS automation, telescope, pipeline

Division B

#1466

The NAROO program

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The NAROO program has been created at Paris Observatory, Meudon, as a unique centre dedicated to the digitization and the analysis of old astro-photographic plates for scientific purposes, only.

The NAROO digitizer consists of a granite-based Newport-Microcontrol open frame air-bearing XY positioning table, a scientific sCMOS camera, and a telecentric optical system. The machine is placed in an overpressure, air-conditioned, ISO-5 clean room to maintain its positioning stability better than 15 nm, and its accuracy better than 65 nm.

The renewed interest about photographic plates concerns the expansion of the database of transient objects evolving in time, since 1) digitization now makes it possible to measure images with a high level of accuracy and to identify all the available objects, 2) the arrival of the Gaia reference catalogs allows to realize reductions for past observations with today accuracy. The information extracted from such materials can be of an astrometric, photometric, and spectroscopic nature, when not purely imaging, with consequences in planetology, near-Earth asteroid risk assessment, astrophysical phenomena, and general relativity, to mention but a few. Since we invite researchers to use our facilities and digitize their collection (free of charge), we detail current and upcoming uses for the community: precoveries, small bodies, planetary satellites, Sun, Be stars, SMC and LMC observations for example.

KEYWORDS Facilities, Digitization, Photographic plates, NAROO

Division B

#1133

The European VLBI Network Science Vision for 2020-2030

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In this talk I will report on the scientific prospects for the European VLBI Network for the coming decade.

Within the framework of the EC-H2020 project JUMPINGJIVE, the EVN has published a scientific roadmap which addresses the scientific astrophysical areas where VLBI can provide unique contributions. The document shows that the susbtantial contribution of VLBI ranges from cosmology all the way to planetary science. Moreover, the technological advances in this field have made VLBI particularly suitable in the new emerging field of transients and multi-messenger astrophysics.

At present the scientific roadmap is the guideline for the technological developments, which need to be in place for the EVN to meet the expected scientific output and the new challenges posed by the observatories which willl be operational towards the end of the decade.

KEYWORDS EVN, Science, Technology, Operations

Division B

#1109

Advancement of Astronomical Instrumentation in Korea

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Korea has a long history of Astronomical instrumentation. There is the oldest and beautifully preserved Astronomical observatory in the world, CheomSeongDae, which has a record of being built under the reign of Queen Seondeok in 632 ~ 647 AD. During the governance of King Sejong the Great in 15th century, lots of astronomical instruments were developed including astrometric measuring devices, sundials, and star maps. Korea's own calendars were published annually which were adapted from Arabian calendar and adjusted to the location of Korea.

Modern astronomical instrumentation was opened at late 20th century. Yonsei university started photometric observations of eclipsing binaries from 1976. KASI has operated several optical telescopes and radio telescopes, starting from the 60 cm reflector in 1978. Cameras, spectrographs, and receivers have been made for the telescopes. Space instrumentation was followed from the new millenium by developing satellite payloads.

Ten universities teach Astronomy and space science to students and do research works. We now join international projects such as GMT and Sphere-X. In this talk, advancement of Korean Astronomy is reviewed, and prospects of astronomical instrumentation are discussed.

KEYWORDS Instrument, Korea, Cheomseongdae, telescope, camera, receiver, payload

Division B

#252

A survey of geosynchronous debris within OSTS at NRIAG-Egypt

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According to the increasing of Earth-orbiting debris made by humans especially near Geosynchronous orbit (GEO), it has become important to understand long-term GEO object behavior through the detection of these objects and catalog updating. Ground-based Electro-optical sensors are a cost-effective way to detect objects at GEO altitude. Therefore, the optical observation of space debris and artificial satellites (Optical Satellites Tracking Station (OSTS)) has been established by the National Research Institute of Astronomy and Geophysics (NRIAG) at Kottamia, Egypt. OSTS has also collaborated with International Scientific Optical Network (ISON) for optical observation.

The main tasks of this station are developing an efficient optical survey strategy that utilizes the motion of the GEO environment and the known concentrations of current uncontrolled GEO objects to maximize the coverage of GEO space debris while ensuring good visibility/lighting and good information content, test and assess the merit of the new survey strategy through simulation using metrics which include the number of unique objects detected, required telescope movement, and GEO belt coverage; and test and assess the merit of the different survey strategy.

KEYWORDS space debris, Geosynchronous orbit, optical observation, GEO belt coverage

DIVISION C

Education, Outreach and Heritage

Invited & Contributed Talks

Division C

#2820

Making Image Analysis Accessible to the Blind: IDATA and the Afterglow Access Software

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Innovators Developing Accessible Tools for Astronomy is an NSF STEM+C funded project that works to advance knowledge and understanding of best practices in teaching and learning related to computation and computational thinking in astronomy and how participation influences students' attitudes and beliefs about who can engage in science, technology, engineering, and mathematics (STEM) and computing. One project outcome is the Afterglow Access (AgA) software, a free browser-based astronomy software that makes image analysis accessible to the blind and visually impaired through sonification and other BVI accessible features. This presentation highlights AgA software features and updates, and how you can access this tool for use with your own data.

KEYWORDS astronomy, image, software, BVI, accessible

Division C

#2778

SciAccess, Inc.: Best Practices for Accessible Astronomy Outreach

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People with disabilities comprise the world's largest minority group, and yet this 15% of the world's population is severely underrepresented in astronomy. This session is dedicated to breaking down these barriers by equipping participants with the knowledge, perspectives, and resources necessary to become catalysts of change. From inclusive space outreach pedagogies to accessible conference strategies to enabling the future of disabled astronauts, this interactive session will showcase the latest advancements in science accessibility. It will also demonstrate cutting-edge outreach resources, such as data sonification and 3D printed astronomy models, that are empowering the next generation of disabled scientists and engineers.

Session attendees will be invited to critically evaluate the accessibility of their own work environments and challenged to develop inclusive astronomy outreach approaches. This session will showcase the ongoing work of SciAccess, Inc., an international nonprofit dedicated to promoting disability inclusion in STEM, including the results of the past three annual SciAccess conferences. Participants will learn about upcoming SciAccess events and will be invited to join the SciAccess Working Group, providing them with an opportunity to connect with others who are passionate about STEM inclusion. This session will also share lessons learned from the SciAccess Zenith Mentorship Program, an ongoing virtual program that prepares blind and low-vision high school students for careers in astronomy.

SciAccess as an organization is dedicated to making space for all by sharing innovative technologies and accessibility strategies. Attendees will leave with techniques, guidance, and ideas on how they can conduct outreach and mentorship efforts that promote accessibility within their own sectors of astronomy. Participants will be encouraged to rethink diversity, equity, and inclusion as essential priorities that benefit not only marginalized individuals but STEM as a whole. By welcoming new perspectives into the field through accessible outreach and public communication, we are unlocking new talent and ideas, enriching our research, and advancing scientific discoveries for the benefit of all humankind.

KEYWORDS Accessibility, Disability, Diversity, Inclusion, Astronomy, Outreach, SciAccess

Division C

#1803

Centering compassion and interaction in online teaching

Linda Strubbe[1]

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During this COVID-19 pandemic, many instructors have been asked to quickly move their face-to-face classes online. This is challenging for many reasons: many instructors and students don't have experience teaching and learning online; making the transition quickly is difficult; and many students have challenges accessing up-to-date technology, internet, and a quiet place to study. Moreover, all of this is happening against a backdrop of high stress for students and instructors alike. Being compassionate and mindful of equity issues is especially important during this period. At the same time, today's challenges may provide opportunities that can carry forward past the pandemic, to re-create our classes as more compassionate environments — where instructors and students see each other more as whole people and assume best intentions in each other, and instructors place higher value on student agency. In this talk, I'll share research-based principles and strategies for moving courses online that focus on compassion, equity, and interaction; and I'll share examples of how instructors (including me) have been approaching these aspects of teaching physics online. This will draw from our popular article on the website PhysPort (Strubbe & McKagan 2020, https://tinyurl.com/physport-remote), workshops on remote teaching I have co-facilitated (Center for Astronomy Education, American Physical Society New Faculty Workshop), and my experience teaching physics / astronomy online with the University of Central Asia for students in rural mountain communities in Tajikistan, Pakistan and Afghanistan.

KEYWORDS online teaching, equity, compassion

Astronomy for Mental Health and Wellbeing

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This study discusses how astronomy may be useful for mental health and wellbeing, especially for people under quarantine. During the pandemic time, isolated nomads in the Gobi desert of Mongolia found the starry night sky helpful for their mental health and wellbeing.The purpose of this study is to explore potential positive impacts of astronomy for mental health and wellbeing. Mental health and wellbeing issues are major challenges faced by many people in the world during the pandemic. Astronomy as an educational methodology has much to offer to potentially mitigate these varied stress and alienation factors. There will be a workshop integrating astronomy and psychology for mental health and wellbeing in Mongolia in May 2022.We will share guidance on the immersion, enjoyment and inspiration of the night sky, and explore the impacts of understanding the vastness of the universe. The discussion will include how astronomy education can help overcome such psychological and social stress factors as alienation, emotional discontent, antipathies between peoples, anger, disparities, etc. This study will contribute to strategies and initiatives to develop educational psychology and astronomy for mental health.

KEYWORDS astronomy, mental health, wellbeing, pandemic, education, psychology

Division C

#281

ASTROMOVES:
Career Fluctuations due to the COVID-19 Global Pandemic

Jarita Holbrook[1]

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ASTROMOVES is a project exploring the career decision-making of astrophysicists and related scientists, with attention to the role that intersectional identity plays and how factors change in order of importance over time / career stages (Holbrook 2019). Data collection includes recorded interviews of between 1 – 2 hours along with analysis of publicly available data such as CVs, the Outlist (Mao and Blaes 1998), and the Rumour Mill (Anonymous 2020). At the time of this writing, thirty-eight scientists have been interviewed; the majority astrophysicists. When the project started, the Pandemic was not part of the study; however, the astrophysicists' lives were disrupted and altered such that they were eager to talk about it. Extra duties, mental health, job insecurity and new thoughts about how to navigate careers are some of the topics that emerged from the interviews. The findings and discussion suggests ways to support astrophysicists as the Global Pandemic continues and points will be illustrated through film clips and quotes taken from the interviews.

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KEYWORDS COVID-19 Pandemic, Careers, Mobility, Cultural Astronomy, Astrophysicists

Division C

#2557

COMMUNITY EDUCATION TO FOSTER FACILITY ENGAGEMENT: THE EXAMPLE OF THE DKIST DATA TRAINING WORKSHOPS

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Over the last few years, the National Solar Observatory has conducted several "DKIST Data Training Workshops", with the goal of preparing the US and international solar community for the wide variety of data expected from the 4-m Inouye Solar Telescope (DKIST), currently in its Operation Commissioning Phase.

Out of necessity, during the pandemic years the format of the DKIST workshops has evolved to a fully virtual format. Maybe surprisingly, this has turned out to be a very positive experience, quite conducive to the involvement of "non-traditional" attendees such as students from developing countries, or under represented communities. Further, the virtual environment facilitated the workshops' organization, freeing it from most logistical problems and much reducing the associated costs.

In this presentation we'll describe the effort to date, results as derived from post-workshop surveys of participants, as well as possible ways forward adopting a judicious mixture of in-person and virtual workshops to continue supporting the community participation in planning and analyzing observations with the DKIST.

KEYWORDS community involvement, virtual workshops

Division C

#2358

Young astronomer hands-on training with virtual schools

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Recently two long-running EU funded projects, Optical Infrared Coordination Network for Astronomy (OPTICON) and RadioNet, were joined into the newly funded OPTICON-RadioNet-Pilot (ORP) programme. ORP runs a community training programme which delivers expert knowledge in astronomical infrastructure use and development. Here we will present the main educational activities of ORP and its predecessors, especially concentrating on our schools that give hands-on observing experience to young astronomers at professional telescopes. The global pandemic has presented us with considerable challenges as it has been impossible to organise practical on-site training at observatories. In this talk we will discuss our experience from running virtual schools on very hands-on topics.

Keywords:

Division C

#2090

Astronomy lectures in the far away country

Tomasz Mrozek[1], Anna Hildebrandt-Mrozek[2], Soben Sorn[3], Orn Pheoun[3]

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[3]The Global Child, The Global Child, Cambodia

Starting from 10 February 2021, online astronomy lectures were given to students from The Global Child, Siem Reap, Cambodia. The first edition covered 42 lectures given twice per week for grade 7 and separately for grade 9 and 12. Starting from 19 January 2022 we visited TGC and conducted lectures and workshops onsite. The onsite lessons were given until 8 February 2022. In order to enable observational activities we provided the school the telescope (Dobson 8'') with a set of eyepieces and ND foils for Sun observations. Due to ongoing dry season we were able to perform several daylight and nighttime observational sessions. We want to share our experience gained from these activities. It is a one of a kind challenge. First, we are not native speakers who talk to not native speakers about quite complicated astronomical problems. Second, in Cambodia, as it is a developing country, the main attention is given to ensure basic needs to students and to teach them things which can benefit in future life. Therefore, the astronomy may be recognised as a kind of not very desirable knowledge. It gives to students the information about how the Universe works, but it does not give them knowledge useful for finding a job and earn money (in a short term). From such a perspective astronomy is more like a dance or painting lessons which gives you some additional knowledge and skills, not a basic ones. That is why we decided to connect the astronomy with well-being and to show to students that being in touch with the Universe may improve their inner life. It is another one in a kind experience - we connected hard science (astronomy) with improving quality of life (well-being and happiness). After returning to our country we continue online lessons in a scheme 2+1 (two astronomy lectures and one well-being related workshop). The next visit in person is planned for December 2022.

KEYWORDS Outreach, Workshop, Lectures, Cambodia, Astronomy

Division C

#1291

IUCAA Scipop:
Astronomy outreach in India during the COVID era

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The Inter-University Centre for Astronomy and Astrophysics has a rich history of public outreach and teacher training programs in Astronomy via its science popularization (SciPop) program. The COVID-19 pandemic resulted in a shutdown of in-person activities from the beginning of the pandemic. In this talk I will focus on how the SciPop program evolved over the course of two years. I will showcase some of the notable activities that were carried out during the period. To quote some examples: 1) a video series for kids - Story with a Toy, 2) Moon observing challenge 3) Astronomy Crosswords 4) Revisiting Saturday lectures 5) Shared science drive : were some of the activities taken up during the early days. The science popularization team also utilized the annular solar eclipse of 21 June 2020 observed in India and teamed up with the Astronomical Society of India to live stream the event taking pictures from multiple observatory locations. The event included a number of Astronomers speaking to the general public about astronomy. The event featured discussions in multiple Indian languages not only on astronomy but also gender balance in science in general. The event garnered more than 200000 views. Another noteworthy example was the conduct of the National science day celebrations in IUCAA on the 28th February. These open day events normally result in a footfall of more than 10000 students every year, but these events had to be conducted online over the past two years. Virtual tours of the campus and its optical observatory were setup this year, thus opening the campus doors virtually. Online science day competitions which blended art with astronomy in terms of poetry, essay writing and drawing and the little champion winners were given a platform to showcase their work.

I will summarize how the pandemic changed the nature of outreach, and how the IUCAA Scipop team turned adversity into an opportunity.

KEYWORDS Astronomy outreach, IUCAA SciPop, COVID19, Solar eclipse, National Science day India

Division C

#317

Engaging and motivating students using astronomical tools during the COVID-19 pandemic

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Nepal is a beautiful, mountainous country with relatively clear skies at altitude, affording delightful stargazing opportunities. However, many communities are still struggling to establish equal access to primary education. Since the establishment of the Pokhara Astronomical Society in 2012, it has been a priority to use astronomy to promote quality and inspiring education for students and the general public.

We used our best resources, communication skills, and visualization tools to generate interest among students during COVID-19. We collaborated with different schools and took online classes but were concerned about students experiencing anxiety due to the drastically changed education system. Computers and mobile software like Stellarium and star charts made the online class interactive. We encouraged students to conduct small-scale projects using data from the virtual observatories Salsa J and SOHO. Using online robotic telescopes, we engaged students in remote learning and ignited their interest in space science and astronomy. In addition, we held several webcasts with national and international communities to share scientific ideas and career opportunities with students.

We received suggestions from school administrations and parents to plan small group outreach activities as students isolated for a long time from their friends. Following all the protocols from the government, we held star parties and stargazing events with our telescopes. We included hands-on activities like making refractive telescopes from PVC pipes and bamboo, water rockets, and constellation models.

COVID-19 helped introduce digital learning even in remote places, so we intend to build more connections with schools in these areas that will boost education on astronomy and outreach activities in the years to come.

KEYWORDS COVID-19 Pandemic, Increased Screen Time, Astronomy, Hands on Activities, Outreach, Webcasts, Engage Students

Division C

#3072

Benefits and Barriers in the move to online learning with remote telescopes

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By definition, remote or robotic telescopes are remotely accessible. Even when sitting in a physical space, students need to reach into hyperspace to utilize this technology. The last two years has squished not only the students, but teachers, parents and entire schools into hyperspace as well. At face value, this appears to be largely beneficial for remote telescope use – the users now exist in hyperspace along with the telescopes. However, there are a variety of factors – some beneficial and some detrimental – that affect the quality of engagement within the remote space, particularly when considering elements of inclusion and diversity of teachers, students and schools. In this talk, I will outline some of these factors which, while exacerbated by the pandemic, existed in the pre-covid era and will continue on into the future. Most of these factors also apply more generally to astronomy education research and practice.

Keywords:

Division C

#2893

SPACE LIBRARIES: How to use multidisciplinary approaches to reach vulnerable communities through planetary sciences and literature

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From the artistic-informative exercise Love Letter to a space rock, Cintia Durán in collaboration with Xel-Ha Lopez, a young Mexican poet, created Bibliotecas del Espacio (Space Libraries) from the need to show the world of space sciences to remote communities in Mexico.

Space Libraries is an experimental education platform focused on planetary sciences and literature, where the main objective is to start conversations about astronomy and geology, from creative writing exercises and literature, focusing on two groups, which during the COVID-19 pandemic became vulnerable: children and elderly adults in Mexico.

As a result of the pandemic, reflection in the community has become increasingly urgent, to think about how we relate to others, and how we understand accompaniment and care.

Space libraries have carried out workshops in different regions of Mexico and Argentina. We choose creative writing as an instrument, because it allows us to recognize ourselves, to establish relationships with what surrounds us, and ask ourselves questions. In this project our main focus is rocks, from earth or from space. They are the record of the formation of our solar system, they are the memory of unimaginable distances and are part of the history of the universe, and like any library, are always ready to be consulted.

The material for each participant is designed and produced by the authors of this project according to the specific needs of each community, but always with the intention of providing the necessary tools to start a process of investigation and exploration from home. A research focused on sky observation and analysis of terrestrial samples.

KEYWORDS Space, education, Literature, Meteorite, Art, Children, outreach

Division C

#1950

PASEA: Inspiring Future Astronomy Leaders in Africa

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PASEA (the Pan-African School for Emerging Astronomers) is a biannual experiential short course in astronomy for African university students, designed and taught by a team of astronomers and science educators from Africa and across the globe. PASEA's vision is to build a critical mass of astronomers in Africa and exchange ideas about teaching across continents. Founded in 2013 by astronomers based at the University of Toronto and the University of Nigeria, this school has graduated ~250 students from the African continent, many of whom are now graduate students and postdoctoral fellows in astronomy programs around the world.

In this talk, I will be describing our new program featuring a series of remotely deployed observational research projects for ~60 alumni of PASEA in Spring/Summer 2022. This aims to provide a large number of STEM-interested undergraduate students from critically underserved communities the opportunity to gain hands-on research experience, foster their scientific curiosity, and develop their self-identity as scientists. As part of our program, PASEA alumni remotely observe short-timescale transient/variable targets over a three-week period with the Las Cumbres Observatory (LCO) telescope network. Under the guidance of career astronomers, students collaboratively plan their observations and develop the coding, photometry, and light curve analysis skills necessary to interpret their LCO data. I will also discuss our unique pedagogical approach featuring adaptive, inquiry-based learning and our methods for establishing an inclusive, equitable teaching environment for project coordinators to enrich their educational and science communication skills. This new PASEA initiative aims to provide access to studying the Universe to young people from historically underrepresented groups and to inspire the next generation of leaders in astronomical instrumentation and data science.

KEYWORDS Africa, outreach, education, observational astronomy, IAU OAD, time series analysis, transient astronomy

Division C
#853

Launch of the new Astronomy Day in Schools (ADiS) and its results to date

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"Astronomy Day in Schools" was started as an IAU100 Global Project with the vision of mobilizing the astronomical community to organize activities in schools, especially on the occasion of the transit of Mercury in 2019. The sub WG of Astronomy Day in Schools, under the WG of Astronomy Education Research & Methods of the Commission C1, has been calling out again especially in conjunction with the equinoxes, solstices, and other major astronomical phenomena. Equinoxes and solstices are not only astronomically significant around the world, but they are also important phenomena in the history of science, and are connected to cultural events in various regions, making them suitable subjects for educational practice that combines science, history, culture, and STEAM education and good gateways to the world of astronomy and science for teachers regardless of their fields. The project website (https://adis.narit.or.th/) is hosted by the National Astronomical Research Institute of Thailand (NARIT) since 2021. A collaboration led by the Iranian Teachers Astronomy Union and Students' International Network of Astronomy in Iran, has allowed this project to organize online exchange meetings on occasion of the equinoxes and solstices. This has given students around the world an opportunity to introduce their school studies, daily life, and culture in their respective countries. We have held the events five times: March equinox, June solstice, September equinox, December solstice in 2021 and March equinox 2022; and thirteen countries have been participated so far: Iran, Japan, Malaysia, India, Bulgaria, Romania, Spain, Italy, Tanzania, Brazil, Mexico, Thailand, and Qatar. We have shared various kinds of practice related to astronomy with links to local culture, daily life, and community. The NAEC network has been very helpful in publicizing our events and NAECs in several countries have introduced many schools to this event.

KEYWORDS Astronomy Day in Schools, equinox, solstice, teacher, culture

Division C

#2116

Teachers' International Network for Astronomy (TINA)

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When Iranians Teachers' Astronomy Union (ITAU) started its establishment, the objective was to bring teachers in different areas together and to globalize teachers' attitudes. The teachers in all areas have direct contact with the people in the society, therefore, they are the most suitable group in the world to build the society. Based on this, we tried to select the most important content to bring together and globalize teachers' attitudes, and we found astronomy as the most important option. With Students and other teachers, we started the core of the teachers' association. Then, by studying the goals and strategy of the UNESCO plan, we tried to adopt the best method. Due to the poverty of the region and the lack of support from governmental and non-governmental institutions, we based the programs and project with the help of our teachers. Although, having a big network of teachers around the world can help us to communicate with other sciences and also can inform the world about the environmental problems and natural awareness.

At first, our field of work was a city, and after a few years we were able to cover a province, and after ten years we had branches in half of the country and after fifteen years in most parts of the country, and all provinces are connected to each other by network system.

The reason for our success is the simplicity of the system and at the same time its usefulness. In this model, each school has a representative in the city teachers' association and each city has a representative in the provincial association, and each province has a representative in the country association. This system helps easily and all are connected to a network and information is provided quickly. After some years now we are seeing that the knowledge of astronomy and relative subjects are more and more in society and teachers are very interested to join and be a part of projects.

At this time we have been providing many events, projects and courses around the world to get more and more teachers involved in cooperation with ADIS, NASE and other IAU offices. We believe that TINA will provide a big community of teachers in order to help all of the astronomical and educational projects related to schools, teachers and society as the "IAU strategy plan" by producing a network of teachers; Help them to join and then follow them to continue

KEYWORDS Astronomy, Education, Teachers, Students, School, Devlopment, Heritage

Division C

#863

Students' International Network for Astronomy (SINA); Overview and the future

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Students' International Network for Astronomy (SINA) was a social group of students in south of Iran since 2014, that was organizing many astronomical activities and projects in the area. The goals were to help students from different cities to communicate with each other using astronomy and let them experience team-work activities and be connected to the nature and environment education.

SINA has not limited itself to domestic activities, but has deepened its connection with foreign countries, especially since 2020. SINA has been organizing many international events of astronomy in relation with cultures, history and societies, in cooperation with Iranian Teachers Astronomy Union (ITAU), Astronomy Day in School (ADiS) and Network for Astronomy School Education (NASE) including the main Persian astronomical ceremonies for ADiS connecting more than thousand students in more than 15 countries around the world.

SINA is also cooperating with Japanese teams to involve and help the big project of "21st version of SILK-ROAD" and cooperating the NASE project in cooperation of UNESCO. Our goal is to let SINA involve many activities and help students join the astronomy society in the world to consider deeply our planet through astronomy education and environmental concerns, and of course help to reach the world peace.

KEYWORDS Students, Education, School, Astronomy, Development, Outreach, Heritage

Division C

#2719

General Relativity in Secondary School - Research-Based Development of Learning Resources and Analyses of Students' Conceptual Understanding

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According to Albert Einstein, common sense is nothing more than a deposit of prejudices laid down in the mind before the age of eighteen. Although experiments have repeatedly confirmed Einstein's ideas about gravity, space and time, astronomy and physics education in schools continue to be dominated by a 19th-century worldview. Consequently, the theory of relativity still contradicts the common sense of many. Aiming to make Einstein's ideas part of the intellectual equipment of young learners, this talk presents an educational reconstruction of general relativity that I undertook in my PhD.

Drawing on the model of educational reconstruction, I proposed a way of turning general relativity into a subject area for secondary school students. The research-based development of a digital learning environment set the stage for studying learning processes and students' conceptual challenges. One key contribution of this PhD-project is the systematic study of secondary students' conceptual understanding of spacetime as a highly abstract concept and the presentation of a new instructional model of curved spacetime.

The recent birth of gravitational wave astronomy and the first-ever taken picture of a black hole create a fantastic vision of astronomy for the future. The findings of this research help teachers bring this vision into science classrooms.

KEYWORDS general relativity, general relativity education, Einsteinian physics education, astronomy education, educational reconstruction

Division C

#2156

Tales about the sky. Orality and mythical analysis in cultural astronomy

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When approaching the study of the astronomies of predominantly oral cultures, it is very common the analysis of mythical tales that involve the sky. But these stories are usually analyzed without taking into account their conditions of production, use and circulation. Nor are the psychodynamics and narrative structures characteristic of orality usually included in these analysis. Mythical stories, in these cultures, do not function as watertight compartments, nor do they imply a set of perfectly defined episodes and characters. These stories and their connections with other stories do not respond to a predetermined pattern of roles and correspondences, but rather, within a semantic field of possibilities provided by the common socio-cultural experience of the narrators and their listeners, the narrators creatively build from -more or less stable- "blocks". The bridges that they draw are not capricious, but are dictated by analogies, formal similarities, similarities of characters, common or relatable elements or episodes, reactions or questions from the audience, context conditions, etc. The recurrence of elements or identifications in different situations and in the mouths of different narrators places them in a wide spectrum from idiosyncratic and sporadic mentions to very stable ones, which almost all narrators mention and give rise to a series of stories that are usually linked. Narrator and audience mutually condition each other and are immersed in a field of interpretive possibilities that exceeds them. There are no "official versions" but people with "authorized word" who build at the time of narration, appealing to a set of elements and meanings that enjoy a certain social consensus.

Thus, taking up the contributions of decades of studies on oral discourse and using South American indigenous groups as an example, we propose to discuss the methodologies of mythical discourse analysis in cultural astronomy and their implications.

KEYWORDS cultural astronomy, orality, myth, methodology, narrative structures, ethnoastronomy, South America

Division C

#1397

Perspectives on Decolonising Astronomy for an Inclusive Environment

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A form of colonisation exists in scientific academia, education and outreach. It is identified through the imbalance of power and wealth between academia in developed and developing countries, Global North and Global South, and Western to East. Also recognised as 'parachute science' wherein experts from formerly mentioned regions would go into under-developed or Global Southern areas for one-off activities without collaboration with local expertise or long-term plans. The issue of 'colonial science' is reflected in astronomy research, development, education and outreach. These colonial structures continue to shape astronomy efforts, which could work against the development of under-developed communities. As a community of astronomy experts, it is essential to consider how resources such as expertise, guidance, and materials are shared among the communities. And collaborations that go hand-in-hand with local experts and address local needs. This talk will address the growing concern of 'parachute science' or 'colonial science' in astronomy and move towards an inclusive environment.

KEYWORDS Decolonising astronomy, Astronomy outreach, Colonial science, Parachute science, Astronomy education, Astronomy development, Inclusive astronomy

Division C

#2811

Hawai'i Astronomy: Traditional and Modern Methods

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With Maunakea as its preferred site, TMT is invested in serving as a conscientious and committed partner with the Hawai'i community. TMT is listening to and learning from communities in Hawai'i, particularly Native Hawaiian communities, and investing in a future together. Native Hawaiians are astronomers. Just as modern astronomy practices observations of celestial objects to learn more about our universe, so did Hawaiian communities practice observational science in order to care for the land and its people.

This presentation is the second of a two-part series. Take a closer look at the context in which astronomy exists in Hawai'i today. From traditional astronomy methods (many of which are still practiced) through the turbulent history of Hawai'i (from Monarchy to State) and ending with the current position of modern astronomy including the status of the Thirty Meter Telescope (TMT) and its work in the community today. Understanding Hawai'i Astronomy today, including its traditional and modern methods, allows us to better meet the needs of the many Hawai'i communities and informs the new community based approach of the TMT project.

KEYWORDS Hawaii, Maunakea, Native Hawaiian, traditional astronomy

Division C

#741

Astronomical skills of fishing communities in Western India

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We report an account of how fishermen communities in the Western Indian state of Maharashtra use indigenous knowledge of astronomy in their life, including their calendrical practices and navigation. The respondents in our study are older fishermen with little or no formal education. Yet, they have their own unique interpretation of the sky which is influenced by their surrounding experiences.

These communities possess skills to determine local time, directions, tides, onset of monsoon, changes in weather, etc. based on the lunar observations and certain constellations. They exhibited in-depth knowledge about the phases of the moon, moonrise timings and tides. For example, they could readily explain how time of tides could be calculated, a concept that many urban school students find challenging. They could also state unambiguously that the North in the compass actually makes a non-zero angle with the direction of the pole star.

We will describe our experiences, data collection method and associated challenges and how these pieces of information would eventually lead to creation of locally relevant astronomy content for school education among these communities.

KEYWORDS Cultural Astronomy, Constellations, Directions, Tides

Division C

#600

Listening to Other Voices: Culturally Sensitive Sites Committee

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We present a joint initiative between the IAU Division C Working Group on Astronomy in Culture (WGAC), the Royal Astronomical Society (RAS), and the American Astronomical Society (AAS) committed to tackling problems related to astronomical sites with Indigenous sensitivities. The Culturally Sensitive Sites committee applies what we have learned in decades of cultural astronomy studies, so that the astronomical community will better understand the conceptions, values, political tensions, and cultural interests at stake when seeking to install and maintain astronomical facilities. The controversy over building the Thirty Meter Telescope (TMT) on Maunakea, Hawaiʻi, is a well-known example of the type of conflict that can arise.

Beyond the conflicts and how to avoid them, we believe that it is of utmost importance for astronomers to collaborate with researchers in disciplines that are familiar with and address these issues. Cultural astronomy is an interdisciplinary area in which astronomers, anthropologists, historians, archaeologists, sociologists, and others can work together and exchange valuable information. Thus, these disciplines have experts who have been studying what that the installation of an astronomical complex implies for the local population.

We believe that communication, to be real and deep, must go both ways; local and indigenous communities have things to say to astronomers. It is our charge to listen to them and learn from them.

Of importance is to build an interdisciplinary effort that brings together experts within the astrophysics community and beyond who have been engaged with these issues, priorities, and communities. This session introduces the initiative, reports on recent activities, and invites participation by IAU members who are invested in these issues. We seek to enlighten all who listen. The path forward can only be forged by recognizing the past and acting for our future. Einstein himself said “we cannot solve our problems with the same thinking we used when we created them.”

KEYWORDS Cultural Astronomy, Indigenous, Sensitivities, Thirty Meter Telescope, SKA, Maunakea, Sacred Sites

Division C

#410

Ireland's Historic Observatories and their intersection with science, culture and politics

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Ireland has three heritage observatories at Armagh, Birr and Dunsink. Known for the NGC catalogue and the discovery of the spiral nebulae, key elements in the design of observatories and the development of telescope through the 19th century can be still be seen in their suite of historic telescopes. They also remain active centres for science, Armagh and Dunsink hosting research groups and Birr the LOFAR telescope.

Yet these observatories are much more than this, they are integral parts of their communities and have contributed to the culture and politics of the society they are part of.

For instance, Armagh and Dunsink came together during the partition of Ireland to forge the first collaboration supported by the two governments, north and south, in the island to build the ADH Telescope in South Africa. This helped contribute to dialogue between the governments at a time when they could not be seen to publicly engage with each other.

Today, their heritage underpins a resilience that has contributed to their survival through hard times and to flourishing in good times. The science centre at Birr is now a major tourist attraction that is a key economic contributor to its region. Armagh and Dunsink have developed vigorous education and outreach programmes around their astronomical research activities that complement them and serve to inspire.

All face challenges to ensure their future vibrancy, planned developments around them which could detract from heritage and impact on mission. However this also offer opportunities. The importance of the Observatories as trusted voices, able to speak authoritatively about science in a world where fake news and disinformation proliferate, gives them a role in society that goes beyond the research they undertake. The challenge is how to utilise this intersection of culture and science so they can continue to thrive and contribute to the growth of society as well as to astronomy.

KEYWORDS Heritage, Observatories, Ireland, Culture, Armagh, Birr, Dunsink

Division C

#2897

OruMbya - Astronomy as fuel of life: the resilience of stars in Yoruba, Afro-Brazilian and Indigenous Cosmogony

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OruMbya (Orum, sky in Yorubá, and Mbya, a Brazilian Guarani ethnicity) is a pilot project to celebrate Astronomy as a fuel of life, in which the stories of the stars preserved in the resilience of people from three different continents have been shared over months, through scientific-cultural activities focused on the dissemination of knowledge, promotion of social inclusion and sustainable development in the context of PLOAD. In this first experience, the hosts are the NGO Casa da Tia Ciata and the cultural centre “Remanescentes da Tia Ciata”, milestone of defence and preservation of afro-brazilian memories in Rio, and the centenary Observatory of Valongo (OV), one of the oldest institutions of Astronomy in Brazil. The two institutions are located in Morro da Conceição (within the Little Africa region), an iconic place of resistance and reaffirmation of black identity, one of the most socially vulnerable urban regions in Rio. We organized five public webinar, the last being semi-presential at the Observatory of Valongo. Every event consisted of the organic combination of three experiences dedicated to astronomy, African and Indigenous knowledge, and art or music, which were recorded and live broadcasted. Locally, we organised a workshop with children from a nearby favela (Morro da Providencia), where we planted together organically and equally cultivated traditional herbs used in Afro-Indigeneous cultures. We also produced two outreach videos to disseminate the project main ideas (a tour of the Little Africa region and the construction of the horta). An e-booklet is being created at the present moment with the material and photos of the organised events. The outcomes of this project will be publically available for downloading and streaming in the site of the OV, Casa da Tia Ciata and PLOAD. Our activities attracted a diverse public (children, young and adults), leading toward an interesting and healthy sharing of life experiences.

KEYWORDS education, outreach, SDGs, heritage, OAD projects

Division C

#2340

Astronomy in schools: science, history and culture together

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This work begins by approaching the importance of Content, Pedagogical and Curricular knowledge aiming the formation and performance of teachers in schools. But, only the traditional knowledge transfer does not consider the diversity of students in a class, school, community, city, state, or country. Each teacher needs to know any basic content and the curriculum of the school or country and pedagogical aspects using different methodologies to promote student learning. Astronomy, one of the most interdisciplinary areas of knowledge, can take into account aspects related to basic, historical and cultural contents. The opportunity to observe the sky, sunrise and sunset any day or on the dates of Equinoxes and Solstices, is important to motivate the acquisition of knowledge by students and teachers. The closed disciplines prevent the understanding of the world's problems. The interdisciplinary and transdisciplinary approach may unite cultures with a more complex vision of the world. The specific contents have been fragmented and different cultures need to unite the regional and the global. The world cannot be something that includes a homogeneous civilization for everyone at the same time. It is necessary to defend the quality of life uniting cultures and enjoying life with freedom, love, friendship and parties. Culture considering history, literature and art are ways to know the human being and arouse interest in Astronomy and other disciplines. The Project Astronomy Day in Schools (ADiS) aims to promote projects in collaborations with amateur or professional astronomers, teachers and students. As a suggestion, this work presents classifications on: calendars, seasons, constellations, events, cultures, places and countries, and art as: music, theater and paintings throughout history. Finally, different teaching methodologies are presented to involve, motivate and reach students in their classes, considering connections with other cultures and helping underserved communities.

KEYWORDS Astronomy, schools, teachers, students, science, history, culture

Division C

#1930

Performance and application of the radio telescope in Gwacheon National Science Museum

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Gwacheon National Science Museum has a 7.2m radio telescope, the only telescope owned by the National Science Museum in Korea. In 2020, we made performance improvements and achieved better observation performance than before. We have developed two educational programs using radio telescopes. The remote observation mode, which provides better access to students from other regions, has also been adopted for data reduction and analysis. We will present its performance, observations made by our students through this program and their scientific results.

KEYWORDS Radio, Radio telescope, Remote observation

Division C

#315

Between Cosmology and Consciousness: Fathoming of the Fabric of the Infinite at the Nexus of Ancient and New Cosmologies

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Intriguing to many in the modern astrophysics community may be the realization that ancient cosmologies, approximately 2000 years old, proposed infinite universes and refer to the flaming lotus whirls populating space – known to us as galaxies. These ideas are discussed in utmost detail in Buddhist treatises widely shared in both China, Korea and other parts of Asia since antiquity. One particular treatise, called in Sanskrit "The Avatamsaka Sutra", translated as Wua Yen in Chinese and as "The Flower Ornament" in English, is recognized as the premier cosmological text in Buddhist literature, delving deeply into the concept of infinity and the unfathomable nature of ultimate reality. Powers of ten are enumerated up to and including the inconceivable. Though we may think of the multiverse as a contemporary conjuration of the mathematical cosmological mind, there in Wua Yen Buddhism we are told there are far more universes and worlds than inconceivably many infinities, that populate the unfathomable, more than all the grains of sand on all the beaches of the world.

The concept of infinity, or infinite infinities dates back in recorded mathematical concepts to the early Jain philosophy, wherein set theory as precursor to Cantorian mathematics was already well articulated and developed. As we are here in Asia, it seems appropriate to acknowledge and trace some of these far earlier historical foundations of cosmology in human cultures and civilizations, lest we brush with the arrogance of ignorance, thinking only our modern astrophysics has pondered these deeper realities. While European philosophy placed the earth at the center of an Empyrean of starry spheres made of other stuff entirely, Asian cosmologies were acknowledging much of what we understand to be the fabric of reality in our 21st Century physics, astrophysics and cosmology. This talk explores some of these conjunctions of ancient and future knowledge, insight and wisdom at the astronomical frontiers.

KEYWORDS Cosmology, Infinity, Universes, Philosophy, Asian, Culture, Mathematics

Division C
#3462

COSMOGRAPHY: THE SCIENCE O THE TWO ORBS. THE ROLE OF AL-ANDALUS

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This thesis analyzes cosmography from its beginnings in Mesopotamia, through a holistic perspective. It examines the advances of this scientific discipline in the different historical moments, showing the interconnections between different civilizations and historical moments. Cosmography has been essential when build the mental image that different cultures have had of the universe and as a source of literary inspiration. Finally, it delves into all the elements that contributed to the appearance of the Scientific Revolution: from the recovery of knowledge of Antiquity and the reinterpretation carried out by the Islamic civilization, and the relative return to the classical values and the role of Humanism. Two interrelated problems have received special attention: The «longitude problem», along with the role that Portugal and Spain had in its solution; and on the size and shape of the planet. In this talk, I will focus on the Islamic Cosmography, specially in Al-Andalus, and its impact on the European Science after the XIII century.

KEYWORDS

Division C

#251

The conquest of the Moon. The history, the legacies and the cultural influence of the Moon landing. Analysis of the Italian media phenomenon as an example of pop science

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This research aims to analyse how the conquest of the Moon has been a technical and scientific goal and has had a great historical and cultural relevance. This work originates from the literary and cinematographic fascination and spreads, through the science fiction genre, to the so-called 'Moon Years'. The discussion proceeds with the analysis of the history of the conquest starting from the ashes of the war and it focuses on decision-making, on propaganda and on the technological push that allowed the Apollo program to achieve one of the most ambitious goals in the history of humanity. I have examined the articles published on the two top newspapers and the two main Italian weekly magazines from 1968 to 1970 in order to verify how the press and television approached the missions. The readers' interest confirm the 'popular dimension' of the Moon landing and that is why it can be considered as a case of pop science. Among all the legacies of the golden years of space age, I have mentioned the patents, the beginning of international collaborations, along with the spread of the Moon landing conspiracy theories and the new frontiers of space exploration.

KEYWORDS moon, landing, pop, science, anniversary, space, exploration

e-Posters

Division C

#3404

Study on the stars recorded in 『Hungaitongxiantushuo』

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In 1607, Chinese astronomer Li Zhi-zao (1565-1631), an astronomer in the Ming Dynasty, edited 『Hungaitongxiantushuo』. This book, one of the astronomical books in East-Asia, contains a table in which the coordinate and magnitude of stars are cataloged into three types: 1) ecliptic longitude and declination, 2) equatorial lodge degrees and polar distance degrees, 3) ecliptic longitude and ecliptic latitude. In this study, we analyzed closely at the star data included in 『Hungaitongxiantushuo』. According to result, it was confirmed that some of the stars in this book were precession corrected from the star data of 『Almagest』 by Ptolemy. We think that the sidereal data of 『Hungaitongxiantushuo』 will be a good data to compare with the star data recorded in Arab/Islam cultures in the history of the star catalog. In particular, in Joseon dynasty, the last dynasty of Korea, based on 『Hongaitonxiantushuo』, it is known that Yoo Geum (1741-1788), a Joseon scholar, made the “Hongaetonheon-ui”. But, it is not clear how he understood it and applied the contents of 『Hungaitongxiantushuo』. Therefore, our study of star data is expected to enable an in-depth discussion on the production of “Hongaetonheon-ui”.

KEYWORDS history and philosophy of astronomy, astrolabe, Hungaitongxiantushuo, Hongaetonheon-ui, star catalog

Division C

#3403

Analysis of published articles in astronomical journals in Korea

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We present the characteristics of articles published in the Journal of the Korean Astronomical Society (JKAS), and the Journal of Astronomy and Space Sciences (JASS) from 1968 to 2021. JKAS and JASS are representative astronomical journals in Korea. Some interesting trends are found in our research. In the 1990s, both journals showed increase in quantity of articles. This increase continued from 2009 to 2015, and since then, the number of articles tends to decrease until 2021. However, it should be noted that the number of articles between 2020 and 2021 has to be impacted by the pandemic (COVID-19). It is found in JKAS that the number of articles by a single author is much high that the number of articles by more to two authors. These articles are focused by theory centered research. On the other hand, JASS shows that the proportion of three authors is the highest, and group centered research is the main focus. In other words, it can be assumed that JKAS shows the characteristics of basic research and JASS shows the characteristics of applied research. We think that the contrasting characteristics of the two journals show room for synergistic effects in Korean astronomy in the future. Therefore, it is necessary to not be deterred by the decreasing trends of the quantitative aspect, but to respond well by determining a future roadmap. We will discuss others interesting points of view concerning the future of Korean astronomy in more detail.

KEYWORDS history and philosophy of astronomy, sociology of astronomy, publications, journal, JKAS, JASS

Division C

#3377

A Study on the Solar and Lunar Eclipse, and the Star intrusion by the Moon & Planets on the Goryeo Dynasty in Korea

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The authentic history of Korea was commenced by the Three Kingdoms period (Goguryeo, Silla, and Baekje, B.C. 57~ A.D. 935) and continued to the Goryeo (A.D. 918~1392) and the Joseon (A.D. 1392~1910) dynasty. Over the past 2,000 years, Koreans have recorded a great deal of astronomical phenomena. We selected the Goryeo Dynasty among them and collected about 5,300 data, and classified them into 17 types according to their characteristics.

This study aims to investigate the recorded data of solar and lunar eclipse, and star intrusion by the moon & planets among each astronomical phenomenon.

There are 138 records of solar eclipses during the Goryeo Dynasty. In fact, there were about 18 cases in which solar eclipses that did not occur at this time, whereas in some cases, the actual occured solar eclipses were not recorded. There were 227 lunar eclipses during the same period. The record of lunar eclipses includes four lunar eclipses that did not actually occur.

The records of stars and five planets were invaded by the moon was about 1800 cases, one-third of total. Among them, 406 star name were identified when the moon invaded the star. Especially, stars near the ecliptic, such as 5β Vir, 77σ Leo, Spica and Regulus, have been invaded more than 20 times by the moon. On the other hand, there were 924 cases in which five planets invaded the stars, of those 341 star name were identifiable. And of those data, 138 cases, about 40 percent, were invaded by Mars.

In addition, the star of the same name included in several oriental constellations. Therefore, if it didn't record the constellation name, it was difficult to identify stars. Such stars had to be located using a simulation program. There have been 14 such stars. In the future, this study will be further extended to other astronomical phenomena.

KEYWORDS Goryeo astronomical phenomena, solar eclipse, star intrusion by moon

Division C

#3146

Model of the Armillary Sphere Driven by Weight Power in Late Joseon Dynasty

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We introduce the model of the armillary sphere of Tongcheon-ui (Pan-celestial Armillary Sphere) developed by the National Science Museum and Korea Astronomy and Space Science Institute in 2021. Tongcheon-ui is described in Damheonseo, Anthology of Hong, Dae-Yong (1731-1783), a pragmatic Neo-Confucian much interested in astronomy in the late Joseon Dynasty. Hong built Tongcheon-ui with help from Na, Kyung-Jeok (1690-1762) and Ann, Cheo-In (1710-1787). Tongcheon-ui consists of an armillary sphere and a lantern clock; the former is a sun and a moon's miniature-moving part, and the latter is the part generating the power to rotate this armilla. This armillary sphere that is preserved at the Korean Christian Museum of Soongil University is widely believed to have been constructed by Hong. Hong's armillary sphere displays a mechanism rotating the ecliptic and the Moon-pass rings and is depicted in Damheonseo. Tongcheon-ui's armillary sphere is constructed in the fashion of a two-layer sphere: the outer sphere is fixed (called Yukhab-ui); and the inner sphere is rotated around the polar axis (called Samsin-ui) with the equatorial, the ecliptic, and the Moon-pass rings. The solar miniature that reproduces the annual motion of the Sun is attached to a 365-toothed inner gear on the ecliptic ring. Similarly, the lunar miniature that reproduces the orbital motion of the Moon is attached to a 114-toothed inner gear installed in the Moon-pass ring. Twenty-seven pins beneath the Moon-pass ring produce moon phase changes. An earth plate representing a world map is fixed horizontally at the center of the armillary sphere.

KEYWORDS old instrument, Armillary Sphere

Division C

#3139

Revista Mexicana de Astronomía y Astrofísica – A Long Journey

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This journal was started in 1974 in response to the need of a channel for communicating the work of the Mexican and Latin American colleagues. As expected, it has evolved to become a respected publication among the astronomical community. We present its evolution and development.

KEYWORDS publications

Division C

#3008

A Study on the Copper Scheduled Plates of Automatic Striking Clepsydra in Early Joseon Dynasty

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In 2021, a number of copper products from the 15th to 16th centuries were excavated from strata in Insa-dong, Seoul. Among those products, there was a jar containing pieces of copper plates that were cut intentionally. The Sudo Institute of Cultural Heritage (SICH) retrieved these pieces and connected them, and as a result, a certain form of copper plate was completed. This copper plate has several circular holes, and cylindrical copper products that fit into the holes were also excavated. Through literature research, it was closely examined whether these relics match with Jujeon (copper scheduled plates) and ball-release apparatus which were recorded in the description of Borugak-nu (automatic striking clepsydra) in Sejong Sillok (Veritable Records of King Sejong). As a result, it was confirmed that they were relics related with Borugak-nu. Considering the dimensions of the excavated relics, the relics were identified as Jujeon of Borugak-nu that were newly restored in 1536 (31st year of King Jungjong's reign). Jujeon is divided into two scheduled plates for 12 double-hours and for night-watches and night-watches divisions that are only used at nighttime. The excavated relics here were scheduled plates for night-watches and night-watches divisions. At that time, copper scheduled plates for night-watches and night-watches divisions were used by replacing 11 copper scheduled plates over a year depending on the length of the night. In this survey, it was found that these were three different types of copper scheduled plates by analyzing the detailed dimensions of the relics. It is expected that a detailed design of the copper scheduled plates will be constructed and the design will be applied to the improved model of Borugak-nu (Operating model produced in 2005, National Palace Museum of Korea).

KEYWORDS automatic striking clepsydra, Jujeon (copper scheduled plates), ball-release apparatus, Veritable Records of King Sejong

Astronomy for All
Busan 2022

Division C

#2819

Reaching for the Stars with the North American Regional Office of Astronomy for Development

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The International Astronomical Union (IAU) North American Regional Office of Astronomy for Development (NA-ROAD) is a collaboration that includes the Adler Planetarium in Chicago, IL, Associated Universities, Inc. (AUI) in Washington, D.C., Association of Universities for Research in Astronomy (AURA) in Washington, DC, Geneva Lake Astrophysics and STEAM, (GLAS Education) in Williams Bay, WI, and the Office of Astronomy for Development in Cape Town, South Africa. The NA-ROAD is working to use the power of astronomy to facilitate economic, social, and educational development across North America including the United States and U.S. Territories, Canada, Mexico, Greenland, and the island nations of the Caribbean. NA-ROAD efforts target five specific areas: 1) astronomy for science diplomacy through collaborative activities that bridge across countries and cultures, 2) use of astronomy and astronomy facilities/resources to support economic development in local communities, 3) use astronomy to facilitate STEM interest, education and outreach, 4) the use of astronomy to promote STEM interest, careers and employment for incarcerated individuals, and 5) advance collaboration and sharing of astronomical knowledges to support the general well-being of Indigenous communities and peoples. Come learn about this new initiative and how you can engage with the NA-ROAD.

KEYWORDS astronomy, development, North America

Division C

#2768

Methods to attract children to reading and astronomy in new ways

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Children's enthusiasm for reading at a young age is so great. One of the most important things that can maintain this passion is to use methods that make reading more enjoyable for children and even make them eager to read by writing and make books as a way they are easier to read.

Many different books for children in the world are written and published annually. One of the things that can be done to get children with different personalities and morals interested in reading a book and learn to use different methods for different and coherent characters for a book, is to subconsciously along with the pleasure of reading, scientific content and astronomy.

To maintain children's enthusiasm for learning astronomy, and reading books, as well as educate children to love books and reading; We need to use new and lovely methods for children

KEYWORDS

Division C

#2755

City of stars

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The Silk Road passed a long way from eastern Asia to the western Europe. In the road we can pass many different countries with different cultures. The goal is that using culture and astronomy to make a connection between these cultures.

The "city of stars" project is about making a network between one city in each country using the same latitudes from east to west so by meaning that people in these cities can see the exact and the same sky. Using this network now they can share their culture and idea about astronomy in their cultures and they will be able to share what they learn in their own countries and in this way countries can connect together.

KEYWORDS City of stars, Silk road

Division C

#2587

Astrotourism Development in Yoron Island, Japan: Perspectives and Potential

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In recent years, (terrestrial) astrotourism (AT), which is based on the interest of tourists in sky-related activities such as dark sky observation and astrophotography has started to attract an increasing number of tourists and academic researchers. AT is seen as an innovative form of tourism that contributes to sustainable tourism development based on the ‘triple bottom line’ concept. Specifically, AT is expected to contribute to night-time economy (Economic Bottom Line), promote educational activities to prevent light pollution (Environmental Bottom Line), and help towards the inheritance of star lore in the concerned regions (Socio-Cultural Bottom Line). We are practicing sustainable tourism development centered on AT in Yoron Island, Kagoshima Prefecture, Japan; based on these three pillars, and this report introduces the activities we are engaged in.

First, we offer “The Qualification System for the Astronomy Guide (Japanese system)” to train astro-tour guides. At present, more than 50 local residents have taken the course, and several of them are carrying out some tours. In Yoron Island, AT is a part of the economic income-source for tourism industries. Second, we engage in activities in order to reduce light pollution. Artificial lights impact the ecosystem of the island as well as astronomical observation. Therefore, we have switched to streetlights in some areas of the island with an upward luminous flux ratio of 0. We are also working on a survey to understand the status of streetlights throughout the island, and plan to eventually replace them in order to reduce light pollution. In the future, we aim to be certified by the International Dark-sky Places Program. We are committed to creating an island where tourism and the rich natural environment can coexist. Third, we are conducting ethnographic research on star lore in the island. Ancient people lived by watching the movement of the stars and the moon when there were no clocks and compasses. Also, they know a lot of folk songs related to the stars and the moon. We hope that astro-tour guides can explain their wisdom of life. In order to realize this, we have published several of our findings in a paper, and we will continue to engage on creating a sustainable tourism destination through AT on Yoron Island.

KEYWORDS astrotourism, sustainable tourism development, light pollution, astronomy and education, dark sky, Yoron Island in Japan, star lore

Division C

#2469

Persian ancient astronomy and its impact on the Persian literature

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Astronomy has become deeply connected to our lives and culture. Among the most important is its association with literary and artistic works. For example, NASE, the teacher training program, introduces ancient architecture and myths from around the world related to astronomy. In conjunction with the International Year of Astronomy 2009, the National Astronomical Observatory of Japan has promoted the Asian Myths and Legends of Stars and the Universe Project and recorded myths from 13 countries from East Asia, South Asia, and Pacific regions. Iranian people have paid special attention to the sky and astronomical phenomena since ancient times and they always watched the moon, the Sun and the stars in the sky; therefore, the beliefs of the Iranian people in ancient times about the rotation of the sky, constellations, moon, sun, planets, etc. expanded. Then Iranian poets and writers, most of whom, were themselves astronomers, incorporated these astronomical beliefs in their poems. Astronomy has given rise to various descriptions, similes, allusions, and metaphors in Persian literature; so that we can see the reflection of ancient astronomy in the poems of great Iranian poets such as Khaqani, Hafez, Khayyam, Ferdowsi, Manuchehri, etc. In this article, the reflection of ancient astronomy in Persian literature has been written.

KEYWORDS astroarchaeology, Persian literature, Poets

Division C

#2466

International Tourism development; with combination of culture, environment and astronomy

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Tourism is one of the most important industries in the world and it directly effects the economic system of each country. However it also has a strong connection between culture, history, environment and education of each country. Astronomy is a field that combine all of these areas and using astronomy we can connect special areas together and improve the tourism business in a country.

Iran is a country which a huge culture and history and contains a special nature and society. Iranian people experience a life of many cultural ceremonies and special events during each year of the Persian calendar. There has been some events of Persian ancient ceremonies in cooperation of ADIS and many countries have been participating in these events and enjoyed a event of ceremony, astronomy and culture.

Our idea is about to use our experience in Iran and increase in other countries in order to develop the tourism industries. One part can be carrying out special ceremonies. One can be using deserts of Iran which are very great places to have a very clean sky for observation. There are also some special educational festival such as “sky explorations” in order to combine all of these aspects and help students understand more about the importance of tourism and culture.

KEYWORDS tourism, culture, environment, development, society

Division C

#2429

Čahār-Tāqīes and Solar calendar structures in Iran

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Čahār-Tāqī is a four-columned/pillared structure standing over four corners of a square base, with each couple of them being attached mutually from above through a crescent-type arch, augmented with a dome erected over the whole structure. Čahār-Tāqīes are among fundamental Iranian architectural forms which have been repeatedly used from Sassanid era onwards and through Islamic period.

In this paper we have discussed usings of Sassanid period Čahār-Tāqīes; those such as road stations or milestones, tombs, and solar-calendar structures.

KEYWORDS Chahar-taqi, Solar-calendar structures

Division C

#2418

Community engagement vs one-directional outreach

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The Community Engagement hub of the recently constituted IAU Centre for the Protection of the Dark and Quiet Sky from Satellite Constellations Interference (CPS) will experiment novel approaches to an active bilateral collaboration bewteen the society at large and its actions for the protection of the pristine appearance of the night sky. The poster will illustrate the foreseen lines of actions of the CPS within the Community Engagement hub.

KEYWORDS

Astronomy for All
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Division C

#2368

Proactive Learning through the Project to Maintain and Utilize "Satoyama" as a Recreation place "Stargazing Forest" by Students of Agriculture and Forestry High School in Japan and the Practice of the Partial Lunar Eclipse Viewing Event at the Place

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A Satoyama is a small mountain adjacent to a village, whereby residents have obtained and utilized firewood and other goods necessary for daily life while maintaining it in Japan. However, in recent years, many Satoyama have not been effectively maintained and have fallen into disrepair, becoming one of the causes of landslides and other disasters. For continuing the maintenance and utilization of Satoyama, it is necessary to take residents' attention on the role of Satoyama such as a recreation place. Therefore, a project to develop a "Stargazing Forest" as recreation place was initiated by the students at Agriculture and Forestry High School in Japan, with advice by forestry experts and a scientist in astronomy like me. The two objectives of the project were defined as follows: 1. The students design and maintain the place on their own initiative to learn the importance of maintaining and utilizing Satoyama; 2. Increasing public attention on the importance of maintaining and utilizing Satoyama through a partial lunar eclipse gazing party on November 19, 2021 at the place. To prepare for the party, the direction of the eclipse was surveyed using instruments and the number of trees at minimum was cut down, except for useful for daily life. For tracing their learning process through the project, we took digital tool “digital Diamond Mandala Matrix” (dDMM), which can be used like mind map both in-person and online. Before starting the project, they filled dDMM with a theme “What is important in maintaining Satoyama?”. After completing the project, they summarized their learning into dDMM with a theme “How to continue to maintain Satoyama?”. And they also answered to questions such as "Changes in perspective before and after the project?". The dDMM data and their answers indicate that both objectives had been accomplished and that they have become interested in the universe and felt the joy of presenting their results of the project to the residents. It was also found that they broadened their perspective and thought the maintenance and utilization of Satoyama more practically through the experience. The project was taken by students whose curriculum did not include astronomy. Therefore, this is a good example that people can participate in activities related to astronomy in a variety of ways, even if they do not specialize in astronomy.

KEYWORDS Agriculture and Forestry High School, Non-specialized people in astronomy, Proactive learning, Satoyama, Stargazing Forest, Lunar eclipse, Diamond Mandala Matrix

Division C

#1247

The astronomical and environmental festival of

Mahdi Rokni[1], Hassan Baghbani[2], Fatemeh Baghbani[3], Maryam Papari[4], Rahimeh Foroughi[4], Samaneh Tafazolinia[3], Hossein Khezri[4], Parham Eisvandi Dehnoei[4], Maryam Hadizadeh[4], Hasheminasab[5], Akihiko Tomita[6], Fatemeh Hamidani[3], Reyhaneh Johari[3], Elahe Nikbakht Sarvestani[7]

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The Sky Explorers Festival was one of the projects created by ITAU. The Sky Explorers Festival provides a platform for students to get acquainted with nature and the night sky in a completely real way. One of the sections has the students to get acquainted with their surroundings and collect a good database that is at the service of citizens and officials. Another section is the herbarium, which has the students to collect and classify plants in the area to maintain them. They also explore them in detail.

There are two very good features of this festival. One point is that all sections of the festival are made by the students' performance and teachers have the role of supervisor. Another point is that during the 24 hours of the festival, the students are in the center of the program, preparing food and other necessities on their own responsibility. The festival is implemented in ancient areas with tourism of each region, so it is a great help in the development of tourism industry in various regions.

The Sky Explorer Festival is an opportunity for sustainable development because from the beginning, all participants of different ages, from children to adolescents, learn the capacities of their place of residence through the research they do and also get acquainted with the capacities of other regions through the research.

KEYWORDS Students, School, Environment, Education, Teacher, Astronomy, Development

Division C

#2118

Plan For New Dimension of Teaching Astronomy In Egypt

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Spreading of the astronomical culture in Egypt represents one of the main aims of NOC and AOE of Egypt. During the previous years, we are working on the popular level. Public elementary lecturers in different fields of astronomy and cosmology, had been submitted. Nowadays there not less than 50 national astronomical societies and amateur astronomical clubs. School since in elementary and preparatory stages contains some information about astronomy also in secondary physics books concern by Kepler laws and gravitational effects. But some international books of international systems of educations like IG and American systems contains not more than a chapter. Now we are working on the following axes to develop teaching astronomy not only in Egypt but also in the surrounding Arab countries

1. Training, courses and workshops for science and physics teachers about astronomy.
2. Putting new curricula contain astronomy for different level.
3. Preparing an Arabic Astronomical dictionary.
4. Camps for students from before university to university stages.
5. Books simplifying astronomical sciences and developing explanatory models for all ages

Using all the available facilities at Helwan and Kottamia observatories, Kottamia Center of Scientific Excellence for Astronomy and Space Science (KCScE) and Scientific Society of Astronomy & Space in Egypt (SSASEgypt) , for many of Faculties' students and high schools.

KEYWORDS Education, Egypt, curricula, Astronomy

Division C
#2099

Beyond the borders through introduction of culture and events

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There are a lot of different cultures and traditions around the world. Some of ceremonies can be attached directly with the astronomical events, such as the Iranian Persian celebration for the solstices and equinoxes in the calendar which are ancient and have a deep impact into the society. Nowruz is the most important one and it is a celebration of spring equinox and the new year in Persian calendar. It contains more than 2 weeks of holidays, celebrations and ceremonies from before the new year and after that. Charshanbe-Suri is one of these celebrations which happens in the last Wednesday of the year. It is about preparing a fire, jump on it and sing and dance around the fire. People believe that it means every bad thing, every bad or negative thoughts will be burned in the fire, and they can start the new year fresh with the clear mind. One of the main goals of "21st version if the Silk Road" is to use these ceremonies in order to increase the peace and friendships between cultures. Investigating in the other regions and culture around the world let us know there is something very common to this in South Korea named "Jeju Fire Festival". The idea is about preparing the unused things that they received during the year and make them burn in fire in the last Sunday. In Japan, there are two of major annual events are related to astronomy. One is the Moon admiring evening, on the 15th of August of East Asian lunisolar calendar which is around the mid-September of the present-day western calendar, and the other is the Tanabata star festival, on the 7th of July. The Tanabata festival was originated from Ancient China and has spread throughout East Asia, and each country has a slightly different form of celebration. This idea can give us this opportunity to search the world with "Silk Road" from the eastern Asia to western countries in order to find these kinds of related cultures, then try to publish and share them with the rest of the world.

KEYWORDS culture, tradition, Nowruz, Jeju Fire Festival, Tanabata

Persian ancient astronomy and in its impact on the Persian literature

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Astronomy has become deeply connected to our lives and culture. Among the most important is its association with literary and artistic works. For example, NASE, the teacher training program, introduces ancient architecture and myths from around the world related to astronomy. In conjunction with the International Year of Astronomy 2009, the National Astronomical Observatory of Japan has promoted the Asian Myths and Legends of Stars and the Universe Project and recorded myths from 13 countries from East Asia, South Asia, and Pacific regions. Iranian people have paid special attention to the sky and astronomical phenomena since ancient times and they always watched the moon, the Sun and the stars in the sky; therefore, the beliefs of the Iranian people in ancient times about the rotation of the sky, constellations, moon, sun, planets, etc. expanded. Then Iranian poets and writers, most of whom, were themselves astronomers, incorporated these astronomical beliefs in their poems. Astronomy has given rise to various descriptions, similes, allusions, and metaphors in Persian literature; so that we can see the reflection of ancient astronomy in the poems of great Iranian poets such as Khaqani, Hafez, Khayyam, Ferdowsi, Manuchehri, etc. In this article, the reflection of ancient astronomy in Persian literature has been written.

KEYWORDS astroarchaeology, Persian literature, poets

Division C

#1894

The project "ExoWorld Walk" an innovative way to engage the public from afar

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Our project "ExoWorld Walk in the Botanic Garden of Cluj-Napoca" delivers an educational program for the greater public, using a new scientific (astronomy) "in situ" method: a walk in the botanical garden with five stops that discuss five fundamental astrobiology themes: (1) the uniqueness of Earth and Life, (2) BioSignature and Life Evolution, (3) Evolutionary processes and patterns, (4) Planetary System Formation and (5) Ingredients of Life. Through our interactive posters exhibition placed along the walk path, we inspire new perspectives of the existing scenery, in this way giving the public free access to new knowledge and new interdisciplinary connections between Nature and the Universe, between astronomy and biology, chemistry, geology and so many other scientific disciplines. The walk and the exhibition are available for people to explore in their own time and at their own pace regardless of the pandemic situation or other restrictions. We as organisers are always close by for the public willing to interact with us, through poster embedded QR codes, a dedicated website and occasional open-air workshops. We discuss in detail the novelty of this hybrid method of engaging the public and its benefits.

KEYWORDS Astronomy Outreach, Astrobiology, "in situ" education methods

Division C

#1879

“Astro-Nagano" Project; Activities to maintain the astronomical research environment in cooperation with citizens' astronomical activities

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Nagano Prefecture is located in the mountainous region of Japan, and despite its proximity to Tokyo (200 km), it has a relatively favorable starry sky environment. The Nagano area is an observation site for optical and radio astronomy in Japan, including Kiso Observatory, Institute of Astronomy, School of Science, The University of Tokyo and Nobeyama Radio Observatory(NRO), the National Astronomical Observatory of Japan.

Currently, in order to maintain the observation and research environment and promote regional development, we are collaborating with a total of about 300 people, including astronomers, planetarium and observatory staff, and members of 12 astronomy clubs throughout the Nagano area, under the Catchphrase "Astro-Nagano”.

The "Astro-Nagano” Project activities started in 2016 and have their roots in the "Suwa Astronomy Club," a citizens' astronomy club founded in 1922.

The Suwa area has a high clear sky rate, and there have long been observers of variable stars and sunspots. The Suwa Astronomical Club, the base of these activities, has been in contact with the staff of the Kwasan Observatory of Kyoto University and the Tokyo Astronomical Observatory(TAO) of the University of Tokyo (now NAOJ) since its founding. These interactions between citizens and researchers greatly influenced the establishment of the Optical Observatory (Kiso Observatory) and the Radio Astronomical Observatory (NRO).

Recently, in response to the deterioration of the astronomical observation environment, researchers and citizens' astronomy clubs have been working together to conduct surveys of the starry sky environment and research on the history of astronomy in the region, including the 100 years of the Suwa Astronomical Club, as "citizen science" activities. We hope that these "now" and "history" surveys will generate sympathy among many local citizens and lead to the maintenance of the observing environment in the future.

KEYWORDS Astronomical Club, starry sky environment, cooperation, Astronomical Culture, Suwa Astronomical Club, observing environment, citizen science

Division C

#1772

Unveiling the Universe: promoting access to Astronomy through talking books

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Astronomy not only generates fascination and knowledge about the Universe but also has a social meaning. In the Brazilian curriculum of Basic Education, it is expected that students can reflect on the position of the Earth, the Sun, our galaxies, and the human species in the Universe. Facing that, Astronomy teaching assumes an essential function in the process of the student's recognition of its position and role in the Universe. However, the pandemic period highlighted inequalities in the education field, especially in teaching activities for visually impaired people, due to social isolation and public health issues, countless educational materials have become temporarily unusable, as they are mostly tactile resources. So, to contribute toward filling this gap, the project Accessible Universe at the Federal University of Rio de Janeiro - Valongo Observatory, aims to promote astronomy teaching inclusively and equitably. The project produces low-cost and easily replicable materials on topics about the Earth and Universe to adapt astronomy activities for blind and low vision people. We explore audio tools as didactic resources, intending to reduce the impacts caused by the SARS-CoV-2 pandemic in Brazil on the teaching-learning process of Astronomy. In this work, we present the talking book as an assistive technology for Astronomy teaching for visually impaired people. In partnership with Benjamin Constant Institute (IBC), we developed talking books addressing topics about the Earth and the Universe, in mp3 format, to make them available virtually nationwide. The production took place at IBC, involving the selection of software, studio recordings, voiceover techniques, audio edition, and reviews. Their application allows the engagement of the public in exploring the Universe in times when touch must be preserved.

KEYWORDS astronomy outreach, astronomy education, Accessibility in Astronomy, inclusive education, assistive technology

Division C

#1645

sun's projects and their effections on students astronomy education

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Sun is the most important object of solar system and it directly effects on our human life on the earth. Knowing and learning about the sun can help us understand more about our life and astronomy. It's very important to use some projects in order to teach students and teachers about the sun. Iranian Teachers Astronomy Union (ITAU) in cooperation with Students' International Network for Astronomy (SINA) has been designing and carrying out some project using astronomy education methods in order to help teachers and students learn more about the sun.

In this project first of all our students learn about sun and sun spots. They also learn how to collect solar data from SDO and SOHO, the space telescopes and how to use those data in the project. In phase one many students calculate solar activity with solar spots and in the second phase they use solar coronal mass ejection from sun's corona.

The result was amazing and it was presented at first in the ADIS event of Yalda-Night in the day of December solstice in 2021. There were more than 100 students and teachers has participated only from one city of Iran. Our desire is to use these kind of projects around the world to improve the knowledge of Sun and also try to point out about other issues such as global warming and environmental problem which are directly related to the sun.

KEYWORDS Astronomy, education, sun, development, iran

Division C

#1627

Čahār-Tāqīes and Solar calendar structures in Iran

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There are many different astronomical structures in ancient Persia and all of them had been used to calculate the important astronomical events and dates during the year with a very specific calendar.

Čahār-Tāqī is a four-columned/pillared structure standing over four corners of a square base, with each couple of them being attached mutually from above through a crescent-type arch, augmented with a dome erected over the whole structure. Čahār-Tāqīes are among fundamental Iranian architectural forms which have been repeatedly used from Sassanid era onwards and through Islamic period.

In this paper we have discussed using the Sassanid period Čahār-Tāqīes; those such as road stations or milestones, tombs, and solar-calendar structures.

KEYWORDS astronomy, Solar calendar, stucture, history, iran

The pioneering scientific endeavor of the first Colombian modern astronomer José María González Benito (1843 - 1903)

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Astronomical interest within the current Colombian territory has its roots in the consolidation of the Botanical Expedition of the New Kingdom of Granada, which stimulated the creation of an astronomical observatory in 1803, the first one established in America. After the death of its first director, Francisco José de Caldas, in 1816, during the convulsive independence period, no major astronomical observations were made in the following years, with few exceptions. In this work we delve into the contributions of the astronomer José María González Benito, the main reactivator of the National Astronomical Observatory of Colombia in the second half of the 19th century, pointing out his pioneering efforts that put worldwide attention to it, and to his own private observatory, making him one of the most committed figures to the development of astronomical sciences in Colombia and the most renowned Colombian in the international astronomical research scene of his time.

KEYWORDS José María González Benito, Colombia, Flammarion Observatory, National Astronomical Observatory of Colombia, XIX century

Division C

#1182

Astronomy in Wartime, Iraq as an Example

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Unfortunately, a small percentage of astronomy is actually used in teaching at schools. Most school teachers have no background in astronomy or astronomy teaching there are no specialized school courses in astronomy. Instead, astronomy content can be found in physics Studies.

Hence the challenges we face in spreading astronomical culture, which are represented in the lack of a scientific basis for astronomical sciences spread among the public.

Nevertheless, after establishing (Iraq-NOC) and Iraq's participation in the (NameExoWorlds 2019) project, we can point out a great success in the dissemination of astronomical sciences through the establishment of amateur astronomical teams in all the governorates of Iraq, which worked to establish astronomical camps in heritage and historical places.

In addition to increasing Iraq's participation in all astronomical activities organized by the International Astronomical Union.

In this presentation, we will discuss in detail the difficulties and successes that have been achieved to spread astronomical awareness in a country that suffers from difficult conditions at all levels and is unstable in security, to know the details stay tuned.

KEYWORDS Education, Iraq, Wartime

Division C

#1140

STEM Training - Space in the Classroom

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STEM is the abbreviation of Science, Technology, Engineering and Mathematics, and therefore encompasses several disciplines essential to life (skills) of the 21st century and future solutions.

Astrophysics is a STEM discipline par excellence, which calls on the expertise of different fields (physics, math, chemistry, biology, geography, high technology, engineering, ...). Also, as a subject that stimulates the imagination – and even raises philosophical questions – it can spark interest in STEM disciplines.

We present in this work, the Teacher training program, carried out within the framework of the VLIRUOS (*) project, in order to facilitate the work of teachers and improve student learning. This training allowed them to learn more about the themes of astrophysics, in particular two themes: exoplanets and stars.

Indeed we used the fundamental notions and experimental techniques for the study of variable stars and exoplanets.

We have also presented them with the educational material(**)that they can use in class.

(*) https://www.vliruos.be/en/home/1
(**)Part of this material comes from the ESERO network (European Space Education Resource Office), produced with the support of the European Space Agency.

KEYWORDS STEM, Teacher training, Astrophysic, Exoplanetes, Stars, educational material

Division C

#788

A pop-up exhibition and exhibit cards of JWST

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In these days, pop-up exhibitions in science museums and science centers are increasing, helping enhanced public awareness and appreciation for science issues. The National Science Museum of Korea held a pop-up exhibition of JWST from Dec. 21. 2021 to Feb. 28. 2022.

More than 30,000 people visited and a lot of people were interested in our exhibition. In order to increase the dissemination and utilization of our exhibition contents about JWST in science museums and astronomical observatories of Korea, we have created some exhibition cards.

Exhibit cards may help to plan, make and operate the pop-up exhibit. We are going to introduce our pop-up exhibition and exhibit cards.

KEYWORDS Exhibition, Outreach, JWST, Science Museum

Division C

#3221

NASE and the Workshops in Korea

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Network for Astronomy School Education (NASE) is part of the IAU Division C Working Group Key Initiatives in Education, Outreach, and Development of Astronomy, and has devoted itself to training teachers in astronomy education. NASE courses have been conducted in 70 countries and 9,000 teachers have been trained in more than 300 courses. Over the past two years, three courses have been held in Korea, and all 10 workshops of NASE have been introduced. In this IAUGA2022, a full workshop for Busan teachers will be held for 4 days. NASE highlights are 1) simple and a full set of activities throughout the contents of astronomy school education, 2) hands-on and activity-oriented, 3) communication, sharing, and development of contents, and 4) philosophy of the sustainable system.

KEYWORDS NASE, Education, School, Teacher's Training

Division C

#3081

Refining Ways to Connect Human Culture and Astronomy through Outreach

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Distributed by the Space Telescope Science Institute as part of NASA's Universe of Learning, ViewSpace is a collection of short videos that tells a story through imagery and text and aims to inspire people with the beauty of the universe and wonder of science. However, the stories ViewSpace tells tend to reflect a modern, western view of the sky. When we reference a location in the sky as being in the constellation Orion or we discuss the variability of Betelgeuse, we inherently reference the Greek and Arabic culture these names come from.

The ViewSpace team identified a need to include additional sky cultures so that more diverse audiences can see their own traditions in the sky and all people recognize that astronomy is not monolithic. We have started connecting modern science with stories of the sky in some videos. Our goal is that more people, particularly from non-white/western cultures, will "think about themselves as science learners and develop an identity as someone who knows about, uses, and sometimes contributes to science" [National Research Council. 2009. Learning Science in Informal Environments: People, Places, and Pursuits.] Additionally, we intend for members of the dominant culture in astronomy to recognize the value that different cultures and backgrounds can bring to the field.

Additionally, our approach to connecting science with sky cultures has been constantly evolving over the past few years as we develop new videos. We've been moving towards co-creation and recognize that while we are in a better position than when we started, we still have further to go.

During this talk, we will discuss the reasons for our approach, concrete examples of videos we have created and the sky cultures included, how we have involved people from various cultures, and our intentions for future improvements to our work as we continue to develop these outreach products.

KEYWORDS Outreach, Sky Culture, Co-creation, STEM Identity, Diverse audience

Division C

#2834

Variable Stars in ESA's Gaia – a Citizen Science Project

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Variable Stars in ESA's Gaia – a Citizen Science Project – will have as its main product a catalog of variable stars from ESA's Gaia mission procured by an open community of citizens willing to contribute to this very interesting branch of astronomy. Such a catalog will be complementary to the Variable Stars Catalog published in GACS provided by Gaia Coordination Unit 7 (CU7). The functionality of the project will be built around concepts of the human classification of the time-series dataset for interesting variable star cases, a user friendly citizen-science platform (Zooniverse) and creating channels with community built around the project and CU7 which will be the main consumer of the final product, with a premise that the product shall improve Gaia Variable stars classification published by the Gaia Consortium. Efficiency to build a community will be boosted by a narrative built around and outside the technical platform via the social media channels and other science engagement tools, including world-class graphic designs that will support the main story and gamification attractiveness to the general public.

KEYWORDS gaia, ESA, citizen science, science engagement, science communication, education, zooniverse

Division C

#2810

Community Astronomy: TMT's Approach to Education, Outreach and Community Engagement in Hawai'i

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With Maunakea as its preferred site, TMT is invested in serving as a conscientious and committed partner with the Hawai'i community. TMT is listening to and learning from communities in Hawai'i, particularly Native Hawaiian communities, and investing in a future together. TMT recognizes that in order to build an enduring community-based observatory, the focus must be on creating meaningful long-term partnerships with local communities based on respect, trust, and the protection of nature. Respecting indigenous culture encompasses many aspects, including people, history, traditional knowledge and view of science, and the ancestral connection to land and nature.

This presentation is the first of a two-part series. Here, we describe TMT's ongoing and planned activities in an integrated program of education, outreach, broader impacts, and community engagement in Hawai'i. Themed "Community Partnership in Education," the program is built on the principles of true partnership with Native Hawaiians and local communities, and on diversity, equity, and inclusion. The program is based on inputs from communities in Hawai'i, developed and executed in partnership with local schools, and consistent with Astro2020's vision of community astronomy.

KEYWORDS

Division C

#2365

Outreach Activity through Astronomical Walking Tour with Historical Features to Learn about the Connections Between the Ancient Astronomy Observations Records and Modern Astronomy: "Millennium Trail of Astronomy in Kyoto"

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Three guest stars were recorded in the diary "Meigetsuki" by the poet Fujiwara no Teika. They have been identified as supernovae in modern astronomy and are the subject of research as sites of particle acceleration. These guest stars were found as a result of observations by the "Onmyoji" such as Abe no Seimei and their descendants to find out unusual movements of celestial bodies in the sky for political reasons. One of the guest stars was appeared at A.D.1054 and the current figure is known as "Crab Nebula". Focusing on the connection through 1000 years between ancient astronomical observation records and modern astronomy in Kyoto, we have developed an astronomical walking tour named "Millennium Trail of Astronomy in Kyoto" tour and started since 2011. We take tour participants to places related to topics of the tour and explain as guides the relation between the observation records of such astronomical phenomena as supernova explosions about 1,000 years ago and modern astronomical research using pdfs and movies in iPads. In another course, we explain the creation of the first calendar made by Japanese at 1600's, and show participants stone table on which the astronomical instruments used in those days and how the Seimei 's descendants were involved in its creation. The tour has both a humanities aspect such as history and ancient documents, and a natural science aspect such as astronomy, so participants' interests are various, for example, history, astronomy, and Abe no Seimei. Several guides are originally tour participants and member of us now. So, we host participants with a variety of interests on our tours. In addition, as activities to promote interest in the tours, we also offer "AstroTalk," which consists of an astronomy lecture and a stereoscopic lecture with 3D images and movies. Thus, this is a very important outreach activity to get the public interested in the results of research at the university with a variety of aspects. We hand out questionnaires for participants which consists of closed questions and open-ended questions after these events. We performed analysis of the answers from participants statistically including text data analysis of sentences written in open-ends questions using KH Coder. We will show whom we should focus on when planning an astronomical tour with historical features based on the results.

KEYWORDS Outreach, Walking tour, Meigetsuki, Crab Nebula, Supernova, Text data analysis, KH Coder

Division C

#2367

Practice and Its Analysis of a Real-time Online Flipped Classroom with Digital Supporting Tool "digital Diamond Mandala Matrix" on the Fundamentals of Astronomy at a University in Japan

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Flipped Classroom is considered effective for students' proactive learning. So, we included it into a fundamental course of astronomy at a Japanese University offered to students who belong to humanities or science departments. The course consists of pre-learning, real-time online class, and post-learning. In the pre-learning, students learned with pdf materials and videos which I prepared to explain basic knowledge each week, and filled “digital Diamond Mandala Matrix” (dDMM) based on the theme we instructed. dDMM is the digital supporting tool which can be used like mind map both in-person and online. It consists of a section corresponding to a mind map with the number of vocabularies restricted up to eight and a description field that explains idea using the vocabularies. So, it is an effective tool for composing sentences for students to explain their ideas, because they can input vocabularies as parts of the ideas into the section like mind map and then they compile the ideas to input the description field using the vocabularies. dDMM is suitable for online class where usually only one screen can be shared. The students prepared pre-learning dDMM with the topic that differ almost every week before online class. In online class, they give presentations with their dDMM and discuss them. In some topic, group works were done using dDMM. In post-learning they filled dDMM based on the presentation and discussions. Finally, they wrote own learning portfolios, in which they reflect on their own learning through the course. In order to analyze statistically learning process, we applied text data analysis with KH Coder on pre-learning dDMMs, post-learning dDMMs and portfolios. From the results of the analysis, we found that the diversity between vocabularies used by the students belonged to science department and those belonged to humanities department at the end for the course was smaller than that at the beginning. Thus, the class design of pre-learning, presentation and discussion and group work in real-time online class, and post-learning encourage students of the science and humanities departments to share each other's ideas, broaden their perspectives in thinking by themselves. We will introduce the practice and detailed analysis of this course as an example which leads to effective proactive learning.

KEYWORDS University, Flipped Classroom, Proactive learning, Online class, Diamond Mandala Matrix, Text data analysis, KH Coder

Division C

#2079

Early Days of Atomic Research in India and International Complexities: Meghnad Saha, Homi Bhabha and their relations

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Meghnad Saha, the astrophysicist who in early life faced social exclusion, was also one of the earliest initiators of atomic research in India. He arranged, with the help of Jawaharlal Nehru, to transport parts for a cyclotron from America to the University of Calcutta in 1942 during WWII. Saha and Homi Bhabha, the architect of India's atomic energy establishment that eventually sponsored radio astronomy, enjoyed cordial relations initially. In December 1940 Bhabha delivered a series of lectures on Cosmic Rays at Saha's invitation at Calcutta University that were published in the journal Science and Culture edited by Saha. The relations between the two, however, underwent strains in disagreements about the establishment and agenda of the Atomic Energy Commission of India and the safeguarding the future of Science and Culture. In the face of the post-war American embargo on atomic research materials and information, in December 1947, Saha engaged with the leader of the French Commissariat Energy Atomique, Frederic Joliot-Curie who was open to international collaboration on atomic research. On his return to India, Saha recommended to the Government that India and France cooperate in the development of nuclear energy. Archival material shows that Bhabha in consultation with the Prime Minister of India had initiated a (secret) cooperation program with the French, the details of which were likely unknown to Saha, even when Frederic Joliot-Curie visited India in January 1950 during the inauguration of the Institute of Nuclear Physics in Calcutta (later S.I.N.P.), by the nuclear chemist Irene Joliot-Curie. Saha had refused to be a part of the Atomic Energy Commission in 1948, even at the personal invitation of Nehru and hence he may not have been privy to these developments in 1949-1950. The dynamics of these interpersonal relations in the context of atomic research and international cooperation of the times and their long-range effects in India will be discussed.

KEYWORDS Interdisciplinary astronomy, History of astronomy(1868)

Division C

#1810

Observation of the Earth from the Surface of the Moon and ILOA

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Earth Observation from the Moon surface provides numerous benefits compared to current monitoring sensors located in LEO, GEO, SSO and Sun-Earth Lagrange points: The Moon is a stable, permanent platform with a nearly negligible exosphere, combining the advantages of space-based seeing with those of ground-based facilities. The entire disc of Earth and surrounding near-Earth space environment is visible from most areas of the near side lunar surface, with the spin of Earth allowing daily observation of the entire globe excluding extreme polar areas, which are visible over 14-day alternating intervals – coverage that is unachievable from artificial satellites at this time. Furthermore, the unique vantage point of the lunar surface enables viewing the Earth under changing illumination profiles throughout the 28-day orbital period. While these qualities are widely understood within the astronomical community, astronautical capability has until very recently limited the viability of Earth Observation from the Moon. Currently, given Artemis, International Lunar Research Station and other commercial / national initiatives offering the likelihood of logistical support and human servicing in the near term, a long duration study of whole Earth thermal output, atmosphere, plasmasphere / magnetosphere, weather / climate, geology, and Earth-Moon dynamics is achievable and will provide more precise values for rotation of the Earth / axial precession – so critical and valuable in all manner of navigation and communication calculations – and insight into planetary processes vital to life. The ILO-1 flagship mission of the International Lunar Observatory Association of Hawaii aims to build upon the success of Apollo 16 and Chang'e-3 with long duration, multi-instrument observation of Earth from the summit of Mons Malapert, proximate to planned international south pole lunar bases.

KEYWORDS Earth Observation, Moon Surface, Axial Precession, Earth-Moon

ASTROxSEN: Inclusive Science Communication on Interdisciplinary Astronomy Education and Outreach (Special Education)

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Astronomy is an interdisciplinary science with unique multi-sensory and multiple-intellectual experience to support students with special education needs (SEN) on psychological perspective of science communication. Not only does Astronomy motivate their learning incentives through activities with experiential approaches and learner-centered pedagogies, but it also encourages them to explore their true self, zone of proximal development (ZPD), and personal strengths. SEN students could leave their comfort zones and relieve their stress through "stargazing mindfulness". It is a precious opportunity for participants to temporarily forget the daily issues and worries. By understanding how to manage their emotional expressions under a silent environment, it can be relaxing, enjoyable moments for conversation.

KEYWORDS Special Education, science communication, Astronomy Education, Astronomy Outreach, stargazing, mindfulness, psychology

Division C

#1389

Astronomy Education for All High School Students - Changes in Science Education and Challenges for the Future in Japan

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How are countries trying to implement “Big Ideas in Astronomy” into school education in the future? In this talk, examples of efforts in Japan will be presented. In Japan, the high school curriculum national guidelines that came into effect this year still require students to choose from physics, chemistry, biology, and geology (including a little astronomy) as in the past. Currently, only about 30% of Japanese high school students study astronomy a little. However, in order to solve various problems facing modern society, such as responding to the 3Ss (Socity5.0, SDGs, and STEAM), science, technology, and innovation, maintaining the global environment, and coping with natural disasters, it is not enough to take only some of the subjects that are separated. It is expected to be difficult. Therefore, an educational research group including the speaker is discussing and considering the establishment of a new subject “(tentative name) Basic Science” including "Big Ideas in Astronomy" essence, which integrates the four fields of science, as a required basic subject in the 2030s.

In 2016, the Science Council of Japan released "The Future of High School Science Education" (chaired by Yasushi Suto). https://www.scj.go.jp/ja/info/kohyo/pdf/kohyo-23-t224-1.pdf Based on this proposal, a group to study compulsory science subjects (tentative name), the Basic Science Study Group, was established in February 2021 to discuss the relevance of learning content, contents, and competencies to be fostered in science among its diverse members across disciplinary boundaries. In this presentation, we will introduce the transition of science education in Japan and the contents of the studies conducted by this team.

KEYWORDS Big Ideas in Astronomy, school curriculum national guideline, Socity5.0, SDGs, STEAM, High School Science Education, Science Council of Japan

Division C

#1307

Astronomy Massive Open Online Classes and the Pandemic

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One side-effect of the COVID-19 pandemic has been increased enrollment in online classes. This talk explores the surge in activity in spring 2020 in three massive open online classes (MOOCs) on Astronomy and Astrobiology, offered by Coursera and Udemy. The increase in enrollment was an order of magnitude over a similar time span in previous years. Attendance at live Q&A sessions also increased, by a factor of three. Learners enrolling during the pandemic were more likely to be younger than thirty and less likely to have advanced degrees. A majority were undergraduate students and relatively few were professionals working in technical fields. The largest number of new students were from India and overall, the biggest surge in enrollment came from people in developing countries, particularly in Asia. Those who enrolled during the pandemic were more likely to take the course to get a certificate or to further their career goals than because they had an intrinsic interest in the subject. As the pandemic has abated, enrollments have dropped, but remain above levels in 2019. These results, although limited to MOOCs in astronomy, suggest that new audiences have turned to online classes during the pandemic for gaining credentials or advancing their professional skills. The potential for continuing outreach is substantial.

KEYWORDS MOOCs, online classes, pandemic, informal learning

Division C

#742

Constraining the period of the origin of Indian Lunar Mansions

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Indian Lunar Mansions, known as 'Nakshtra', have been fundamental to Indian calendrical systems, right from the Vedic era. There have been some attempts to determine an epoch when these mansions got defined, based on subjective interpretations of positions of cardinal points at the epoch of definition. However, these attempts have mostly failed to mesh with archaeological evidence.

We attempt to address the question of epoch of definition from another angle. We assume that the choice of particular principle stars of each lunar mansion was the best possible choice for corresponding ecliptic longitude zone and employ precessional calculations to show for which periods in the history, this particular assumption holds true. The method is also useful in disambiguation of certain Nakshtra definitions.

KEYWORDS Lunar Mansions, Epoch of definition, computer simulation

Astronomy for All
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Division C
#532

Virtual Observatory as an Education Tool

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[2]Mathematics, Maulana Azad National Urdu University, Hyderabad, India, India

Education using real astronomy data is a very effective tool. In this poster we shall describe our efforts in two IAU-OAD Projects "Astronomy from Archival Data" and "AstroSprint" to train and teach young undergraduate and post-graduate students using Virtual Observatory Tools. The Science Cases ranged from Exoplanets, Stars, Pulsars, Galaxies, Dark Matter and Gravitational Lensing. We shall discuss the various outcomes of this work and the various lessons learned in. this effort.

KEYWORDS Education, Virtual Observatory, Archival Data, Astronomy

DIVISION D

High Energy Phenomena and Fundamental Physics

Invited & Contributed Talks

Division D

#1078

Fast radio burst detection and differentiation with the CHIME telescope

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Fast radio bursts (FRBs) are millisecond-duration extragalactic radio transients of elusive origin that were first discovered in 2007. The bursts exhibit a variety of time-frequency structures, shaped by an unknown emission mechanism and transformed by propagation through an ionized and inhomogeneous medium. More than twenty FRBs have been observed to repeat, which has ruled out a cataclysmic origin for these source and allows for detailed multi-wavelength follow-up observations. It is as-of-yet unclear whether all FRBs repeat and if there are multiple populations of FRBs. During my PhD, I helped to design and commission the CHIME/FRB survey on the Canadian Hydrogen Intensity Mapping Experiment (CHIME) as well as novel algorithms to characterize the morphology of FRBs. I presented a synthesis of FRB morphology (the change in flux as a function of time and frequency) as detected in the 400--800 MHz octave, using events from the first CHIME/FRB catalog. The catalog properties of the FRBs confirmed that bursts from repeating sources, on average, have larger widths and showed, for the first time, that bursts from repeating sources, on average, are narrower in bandwidth. This difference could be due to beaming or propagation effects, or it could be intrinsic to the populations. In this talk, I will summarize the results from my PhD thesis and present updated population comparisons with new repeating sources of FRBs from CHIME/FRB that I have since been working on.

KEYWORDS Fast radio bursts, Repeating sources of FRBs, Surveys

Division D

#599

Compact binary millisecond pulsars and the neutron star mass distribution

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The maximum mass of a neutron star has important implications across multiple research fields, including astrophysics, nuclear physics and gravitational wave astronomy. Compact binary millisecond pulsars (with orbital periods shorter than about a day) provide a good opportunity to search for the most massive neutron stars. I will review the neutron star mass distribution in light of this growing population of pulsars (also known as "spiders").

KEYWORDS neutron stars, pulsars, interacting binaries, compact binaries, ultradense matter, irradiation, pulsar winds

Division D

#692

Masses and beyond with neutron star cooling

Wynn Ho[1]

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Neutron stars are born extremely hot in the aftermath of a supernova and then cool by neutrino emission over the next million years. The rate at which a neutron star cools depends on the star's mass and properties such as the amount of superfluid or proton-neutron asymmetry in its interior and possible transitions to hyperons or deconfined quarks at ultra-high densities. In this talk, I present comparisons of cooling simulations with (1) X-ray measurements of the temperature of the neutron star in the Cassiopeia A supernova remnant and (2) radio and X-ray measurements of glitches in the spin rate of young pulsars. I demonstrate how theory and observations can not only yield neutron star masses but also a star's superfluid content and more.

KEYWORDS neutron stars, pulsars, nuclear physics, X-rays

Division D
#520

X-ray measurements of neutron star masses and radii

Cole Miller[1]

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Precise and reliable measurements of neutron star radii and masses are essential to our understanding of cold, catalyzed matter beyond nuclear saturation density. After summarizing earlier work, I will focus on results from NASA's Neutron Star Interior Composition Explorer (NICER) satellite, which has provided high-quality data sets that have yielded measurements of the mass (M=1.44+-0.15 Msun) and radius (R=13+1.2-1.0 km) of the 206 Hz pulsar PSR J0030+0451, and of the radius (R=13.7+2.6-1.5 km) of the M=2.08+-0.07 Msun, 346 Hz pulsar PSR J0740+6620. I will discuss our group's work on these pulsars and will in particular detail the assumptions that have gone into our analyses, to help the assessment of our results. I will also discuss the implications of our results for the properties of the dense matter in the cores of neutron stars.

KEYWORDS X-ray, neutron star, equation of state

Division D

#256

SPH simulations of the Induced Gravitational Collapse

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In the IGC paradigm, a carbon-oxygen star (CO$_\mathrm{core}$) collapses and explodes in a supernova (SN), the material ejected in the explosion is gravitational attracted by its companion, a neutron star (NS), taking place a hypercritical accretion process onto it. For compact systems, the accretion rate could be enough high to lead the NS reach its critical mass, collapse in a black hole (BH) and emitted a gamma ray burst (GRB). With the aim to identify the separatrix of systems in which a BH is formed and characterize the observational signatures of each process, we have performed 3D-SPH numerical simulations of the SN expansion under the presence of the NS companion and explored a wide range of the initial parameter space. Additionally, the hydrodynamics inside the accretion flow is studied and we shown that the electron-positron annihilation in neutrinos is the main cooling channel that allow the high accretions rates on the NS.

KEYWORDS Compact Object, Numerical Simulations, GRB, Supernova type Ic

Division D
#3021

GWTC3:
compact objects with different sizes and shapes

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The third Gravitational-wave Transient Catalog describes signals detected with Advanced LIGO and Advanced Virgo up to the end of their third observing run. We have detected 90 compact binary coalescence events which cover broad mass and spin space. These detected compact binary coalescence events give an opportunity to understand black hole and neutron star distribution. In this talk, I'm going to give a short review of the masses of compact objects found by LIGO/Virgo from merger events.

KEYWORDS

Division D

#1971

Could a Unified Spectral Model Estimate the Mass of Accreting Compact Objects?

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Accretion flows around black holes (BH) and neutron stars (NS) emit high energy radiation with varying spectral and timing properties. Observed timing variations, both short and long-term, point to the existence of a mechanism, dictated by the flow dynamics, and not by the stellar surface or magnetic fields, that is common in both. Spectral energy distributions (SED) of multiple sources indicate that the Comptonization process, the dominant mechanism for changing states in X-ray, takes place inside the flow that has similar physical properties in both the objects. In a series of observational and numerical studies, it has been argued that a generalized flow structure (Bhattacharjee 2018), common to both such compact objects, could explain the variations in spectral and timing properties. Recently, a unified spectral model have also been developed, that includes both disc and wind accretion, to simulate and fit SED for 1. different states of evolution, and 2. across the subclasses (BH: Transient, Persistent and Class Variable; NS: Z and Atoll). We note some of the example SED fits of multiple X-Ray binaries (BH: Cygnus X-1, H1743-322, GRS1915+105; and NS: Sco X-1, Cir X-1). As mass of the source is an intrinsic parameter of the model, this model can also be used to obtain mass from each SED fits. Here, we conduct a thorough excursion of flow parameters across different stages of accretion and try to constrain the mass of the compact object. We find that for a broadband SED, that covers disc, boundary layer (for NS) and Comptonized photon frequencies, a reasonable estimate of mass is obtained from SED fittings, agreeing well with previous measurements. When multiple spectral states are used, a tighter constraint on mass can be provided. However, for smaller range of frequency and in presence of absorption due to interstellar medium, the spectral degeneracy can limit the precision of the estimates. We also discuss possible improvements to the model and its usage.

Bhattacharjee, A. 2018, Astrophysics and Space Science Proc., Vol. 53, Exploring the Universe: From Near Space to Extra-Galactic (Heidelberg: Springer), 93

KEYWORDS black holes, neutron stars, accretion, compact objects, radiation dynamics, shock waves, X-ray binaries

Division D

#371

Oversize black holes: Formation channels of the most massive black holes observed by LIGO and Virgo

Michela Mapelli[1]

[1] *Physics and Astronomy Department G. Galilei, University of Padova, Italy*

Pair-instability theory suggests that massive stars cannot leave compact remnants with mass ~60-120 Msun, the so-called pair-instability mass gap. LIGO and Virgo surprisingly observed a few black hole candidates with mass in this range. In this talk, I review the main scenarios which can lead to the formation of such massive black holes. On the one hand, the boundaries of the mass gap might be different from the expected range because of uncertainties on massive star evolution. On the other, dynamics can trigger the formation of massive black holes in many different ways. Dynamically assisted stellar collisions can lead to the formation of exotic stars with oversize envelopes, which can avoid the pair-instability regime and collapse to a black hole directly. Furthermore, hierarchical mergers of stellar-born black holes give birth to black holes in the mass gap and intermediate-mass black holes. Hierarchical mergers are particularly efficient in massive star clusters (such as globular clusters and nuclear star clusters) and in the disk of active galactic nuclei. Finally, I review the possible rates associated with these different channels.

KEYWORDS black holes, pair instability, upper mass gap, LIGO - Virgo, gravitational waves

Division D

#2065

Demography of binary black holes with the population-synthesis code SEVN

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The currently-growing LIGO-Virgo data provides an excellent opportunity to investigate the demography of gravitational-wave sources and their formation channels. One way to study these features is through population-synthesis simulations of the progenitor systems. In this talk we present the last version of the population-synthesis code SEVN (Stellar EVolution N-body). SEVN uses a set of precomputed stellar tracks to interpolate the evolution of star properties on the fly. This is a change of paradigm in the field, since most population synthesis codes rely on fitting formulas to stellar evolution tracks run more than 20 years ago. Also, SEVN implements an up-to-date formalism for the main physical processes happening in interacting binaries that influence the fate of the system and the properties of the compact remnants. In addition, along with dynamical simulations, SEVN could be used to study dynamically-driven formation channels of compact-object binaries, such as the exchange mechanism, which is strongly enhanced in high stellar density systems (e.g. star clusters). We will show the results of our investigation regarding the evolution channels of isolated and dynamically-formed binaries that end as binary black holes, and the formation rate and properties of gravitational-wave progenitors that merge in less than the Hubble time.

KEYWORDS black hole physics, methods: numerical, stars: black holes

What is the maximum mass of stellar mass black holes?

Mathieu Renzo[1]

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The fate of the most massive stars is determined by the runaway production of electron-positron pairs which results in violent pulses before black hole (BH) formation. In the most extreme cases, the entire star is blown apart in a pair-instability supernova leaving no remnant. Only at speculatively high masses, energy losses to nuclear photodisintegration in the core nullifies the effect of pair-production, resulting again in BHs. Thus, stellar evolution robustly predicts a gap in the BH masses. Nevertheless, the features of the BH spectrum revealed by gravitational waves do not match these prediction. This open puzzle has stimulated many theoretical ideas spanning from stellar mergers, accretion, and core-collapse, to nuclear and beyond standard model physics. I will attempt to summarize the rapidly evolving landscape of ideas on how to "fill the gap", and focus in particular on two proposed models: dynamical "wet" collisions between stars in a cluster resulting in peculiar stars avoiding pair instability, and filling the gap "from above" with mass ejection in the collapse of stars too massive for pair-instability.

The "wet" dynamical merger faces several stellar evolution challenges, which can be further investigated leveraging large transient surveys. Similarly, filling the gap "from above" requires extrapolating collapsar models to extremely massive progenitors, but the predictions for the resulting "super-kilonova" transient will soon be constrained by the Roman space telescope.

KEYWORDS

Division D

#649

An IMBH in the most massive globular cluster of M31

Renuka Pechetti[1]

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Intermediate-mass black holes (IMBHs) are the bridge between the stellar-mass black holes and supermassive black holes. They are extremely difficult to observe as their effect on the surrounding stars is much weaker than a supermassive black hole. Hence, they require high-resolution measurements of the nearest possible targets. While only a handful of IMBH candidates exist, they can provide key information on the formation of the initial seeds of supermassive black holes and the origin of the galaxy-black hole scaling relations.

I will present the detection of an IMBH in the center of the most massive globular cluster in the nearest galaxy M31. The mass models for the globular cluster were derived using HST observations and then combined with the high spatial resolution kinematics derived from the adaptive optics GEMINI/NIFS IFU observations. Jeans anisotropic modeling was used to combine the mass models and kinematics to measure the black hole mass. There is a strong evidence suggesting that the cluster is likely the stripped nucleus of a dwarf galaxy, which makes it more likely to host an IMBH. This IMBH detection is more robust than any previous IMBH detection, including those in G1 or Omega Centauri.

KEYWORDS Intermediate-mass black holes, Globular clusters, Andromeda Galaxy, Stripped nuclei, Dynamical Modeling

Division D

#979

Searching for intermediate-mass black holes with gravitational microlensing

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The evidence for intermediate-mass black holes (IMBHs) in the 10^2 - 10^5 M_solar mass range remains scarce. One of the possible methods of detecting and weighting IMBHs is gravitational microlensing. Since the timescale of a microlensing event scales as the square root of the lens mass, the timescales of microlensing events due to IMBHs are expected to be very long, 1-30 years, rendering their detection difficult.

The Optical Gravitational Lensing Experiment (OGLE) is one of the longest-running microlensing experiments that has been observing the Magellanic Clouds for nearly 20 years (2001-2020), enabling one to detect very long-timescale microlensing events that may be due to IMBHs.

I will present some of the most exciting very long-timescale microlensing events discovered in the 20-yr OGLE dataset. I will also discuss constraints on the mass function and frequency of IMBHs that can be inferred from the study of microlensing events detected by OGLE.

KEYWORDS intermediate-mass black holes, gravitational microlensing

Division D

#1959

X-ray searches for intermediate-mass black holes in the local universe

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[2]Centre for Astrophysics and Supercomputing, Swinburne University, Australia
[3]Institute of Astronomy, National Tsing Hua University, Taiwan

Two distinct environments are the best searching ground for active (X-ray bright) intermediate mass black holes (IMBHs): the nuclei of late-type disk galaxies and the outskirts of spheroidal or elliptical galaxies. i) In late-type spirals, the identification of candidate low-mass nuclear black holes is based on scaling relations (M-sigma relation, M_{star}-M_{BH} relation, pitch angle relation), and point-like X-ray detections confirm or at least suggest the presence of a compact object in the galactic nucleus. I give an example of some candidates we have identified in our recent survey of the Virgo Cluster. ii) Off-nuclear IMBHs may be the result of satellite accretion during the assembly of a galactic halo. Focusing the X-ray search on elliptical/spheroidal galaxies reduces the possibility of confusion with stellar-mass super-Eddington sources (ultraluminous X-ray sources), which are more often associated with young stellar populations. Here, the identification of candidate IMBHs is based on their soft, thermal (disk-blackbody) X-ray spectrum with peak temperatures kT_{in} ~ 0.2-0.4 keV at a luminosity L_X ~ 1E41-1E42 erg/s. I will give an example of the two best candidates identified so far through this method.

KEYWORDS black holes, accretion physics, X-rays, accretion disks

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Division D

#3110

Accretion onto black holes across the mass scale

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The most luminous persistent or transient phenomena in the Universe are somewhat related to accretion onto black holes. This is a multi-scale phenomenon that goes from the black hole event horizon to much larger distances, up to galaxies outskirts for super-massive black holes sitting at their centres. Accretion of mass onto black holes is also what allows them to grow over cosmic time. However, an in-depth understanding of all the related observed properties is far from being reached. In my PhD thesis, I have tackled many open questions in this field by bridging the gap between theory and observations in the following ways: (1) by studying the physical origin of one of the most used observational scaling relation in bright active supermassive black holes, and suggesting a way to explain it through the impact of black hole spin on accretion properties; (2) by comparing the observations and physical mechanisms of accretion flows around supermassive and stellar-mass black holes, and finding what properties are mass-invariant; (3) by discovering and studying new rare outliers in the family of accreting massive black holes with the eROSITA X-ray telescope, discovering what is possibly the electromagnetic counterparts of some low-frequency gravitational waves emitters.

KEYWORDS

Division D

#637

Unveiled properties of the supermassive black holes with the Event Horizon Telescope

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[2]-, -,

Black holes have been important astronomical objects to understand physics under the extreme gravitational environment. From a theoretical prediction, now its existence is thought to be universal and its massive relatives, supermassive black holes, are thought to reside at the center of most galaxies. Over decades, many observational efforts throughout radio to gamma-ray have been made to unveil the properties of supermassive black holes including the precise measurements of its mass, and the very long baseline interferometry observations play an important role to resolve its innermost structure with angular resolution of (sub-) milli-arcseconds. Especially, the Event Horizon Telescope (EHT) has revealed the first ever image of black hole shadow from the M87 galaxy proving that general relativity is still valid under the strong gravitational field of supermassive black hole.

In this talk, our current knowledge about supermassive black holes which has been discovered by EHT will be reviewed. This will cover the findings from M87 with the EHT and its multi-wavelength campaign observations that provide such as the better constraints on its mass, magnetic field structure near the event horizon, and the most complete simultaneous multi-wavelength spectrum. The efforts toward the supermassive black hole at the center of our Galaxy, Sagittarius A* (Sgr A*), will be also introduced. This is especially important for more precise tests of general relativity than M87 since the mass and distance of Sgr A* are known more accurately. Besides the two main targets, in addition, the innermost jet structure of active galactic nucleus including the 3C279 and Centaurus A will be presented that provide a sharper look at the formation of radio jet. Lastly, the expected studies with future EHT will be summarized to investigate the finer structure of the vicinity of supermassive black holes with better sensitivity and angular resolution toward more candidates.

KEYWORDS Supermassive Black Hole, Event Horizon Telescope, Active Galactic Nuclei

Division D

#934

Supermassive black hole mass estimates from interferometric spectro-astrometry and reverberation mapping

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Measuring the masses of supermassive black holes (SMBHs) plays a key role in our understanding of black hole growth and galaxy-BH co-evolution over cosmic time. The only available method for measuring black hole masses in large surveys and out to high redshift is based on reverberation mapping (RM). Past RM programs on local AGN established a size-luminosity relation between the radius of the Broad Line Region (BLR) and BH luminosity (RBLR ~Lα) which allows black hole mass estimates from a single AGN spectrum. However, applicability of these local scaling relations to high redshifts is uncertain, and recent velocity-resolved RM studies are starting to indicate a variety of BLR geometries and a previously unknown dependence on the Eddington ratio. Spectro-astrometry with the GRAVITY interferometer at the ESO/VLTI provides a new, direct probe of the BLR spatial and velocity structure which can independently test and break degeneracies in these studies. I will briefly review recent advances in measuring masses of super-massive black holes with both techniques, discuss their respective pros and cons, and outline the potential of combined studies and of upcoming GRAVITY upgrades.

KEYWORDS Supermassive black holes, masses, GRAVITY, interferometry, reverberation mapping, broad line region

Division D

#1988

Investigating the high-luminosity end of the H beta size-luminosity relation based on the 6-year Seoul National University Monitoring Project

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Reverberation mapping (RM) of Active Galactic Nuclei (AGNs) is the primary method to determine AGN broad line region (BLR) sizes and black hole (BH) masses. Most of the current H beta RM sample are low-to-intermediate luminosity AGNs with only a few objects larger than L5100=10^45 erg/s. Here we present the latest result from our 6-year Seoul National University AGN Monitoring Project (SAMP). With hundreds of nights of regularly sampled spectroscopic/photometric observations, we successfully measure H beta lags and BH masses for ~ 30 objects at the luminosity range of L5100 ~ 10^44.0 ~ 45.5 erg/s. This sample enables us to test the H beta size-luminosity relation at the high-luminosity regime, and investigate how the departure from the size-luminosity relation correlates with AGN properties, e.g., Eddington ratios. We will also report other key results, including velocity resolved H beta lags and BLR stratification based on lags of multiple emission lines, and discuss the implication of these results on the BLR properties of high luminosity AGNs.

KEYWORDS Active galaxies, Black holes, Reverberation mapping

Division D

#638

Growing the First Supermassive Black Holes

Thomas Connor[1]

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The 21st Century dawned with the detection of the first supermassive black holes (SMBHs) observed in the first billion years of the Universe (z > 5.6), a population that has now swelled into the hundreds. These include a z=6.3 quasar with a mass of 1.2×1010 $M_\odot$ and a recently discovered quasar observed at z=7.64 (less than 700 Myr after the Big Bang) but with a mass in excess of 109 $M_\odot$. Producing such massive objects so early in cosmic history requires significant, sustained growth from massive, quick-forming seed black holes. In this talk, I will review the current status of this field, focusing on three key aspects: the current population of known SMBHs, the seeding mechanisms and how they are constrained, and pathways for enabling sustained and rapid growth. In particular, I will discuss prospects for further discovery in light of upcoming missions, current methods of black hole mass estimation, and the advances expected by JWST. I will also address the role high energy astrophysics has in exploring this frontier, both in current and planned observatories, including the detection of inverse Compton emission from jets and potentially obscured AGN. Furthermore, I will review current theoretical work on early black hole seed formation.

KEYWORDS Quasars, Early Universe, Supermassive Black Holes

Division D

#641

Supermassive Black Holes and their Host Galaxies

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Supermassive black holes (BHs) are ubiquitous in the center of massive galaxies. When actively growing through accretion, Active Galactic Nuclei (AGNs) become some of the brightest objects in the observable universe. It has been two decades that relations between BH mass and the properties of their host galaxies (such as luminosity, stellar mass and stellar velocity dispersion) were first discovered. Interpreted as evidence for a co-evolution between BHs and

galaxies, these scaling relations remain a hot topic for contemporary studies with many open questions remaining, including the role of AGN feedback or hierarchical merging, and the nature of the host galaxies (elliptical versus spiral galaxies, bars, pseudo-bulges and mergers). Studying the co-evolution as a function of cosmic history can shed light onto origin and fundamental drivers, but relies on AGNs for which host-galaxy properties are intrinsically difficult to measure. I will review our current understanding of the nature and origin of the scaling relations between supermassive black holes and their host galaxies.

KEYWORDS Supermassive Black Holes, Galaxies, Scaling Relations

Division D

#250

What drives the growth of black holes?

Guang Yang[1]

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There are supermassive black holes (SMBHs) in the centers of most massive galaxies. Observations of nearby systems have found that SMBH masses (M_BH) are tightly correlated with host-galaxy properties such as bulge masses (M_bulge). These local SMBH-galaxy relations suggest that SMBH growth is fundamentally linked to host galaxies over cosmic history. Previous studies suggest that long-term average SMBH accretion rate (BHAR) is intrinsically related to star formation rate (SFR) for the overall galaxy population. However, we show that BHAR is more strongly correlated with host-galaxy stellar mass (M_*) rather than SFR, and this BHAR-M_* relation does not depend on cosmic environment. We further quantify this BHAR-M_* relation and its cosmic evolution at z= 0.4–4.

However, we find this BHAR-M_* relation does not hold for bulge-dominated galaxies, and their BHAR primarily depends on SFR. This BHAR-bulge SFR relation indicates that SMBHs only coevolve with galactic bulges rather than the entire galaxies, consistent with the observations of the local universe. Our best-fit BHAR/SFR ratio is similar to the typical M_BH/M_bulge ratio observed in the local systems, indicating that the BHAR-bulge SFR relation is indeed responsible for the local M_BH-M_bulge relation. Our high-resolution hydrodynamical simulations suggest that a compact circum-nuclear disk is the physical mechanism that drives the BHAR-bulge SFR relation. Our recent ALMA observations support this idea.

We have recently applied the BHAR-bulge SFR relation to track cosmic BH accretion density (BHAD) based on the measurements of bulge star-formation history (SFH) from Hubble grism data. Our derived BHAD at z>4 is much higher than those observed from X-ray surveys, indicating that a large population of Compton-thick AGNs is missing from X-ray observations. Future JWST deep surveys will be able to identify these Compton-thick AGNs.

KEYWORDS black hole, AGN, star formation, coevolution, bulge, X-ray, JWST

Division D

#1012

The assembly of the first massive black holes and the prospects of upcoming observations

Kohei Inayoshi[1]

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The existence of supermassive black holes (BHs) within the first billion years of the universe has stimulated numerous ideas for the prompt formation and rapid growth of BHs in the early universe. I will review pathways in which the seeds of massive BHs may have first assembled, and how they may have subsequently grown to be billions of solar mass. I will also highlight recent results of radiation-hydrodynamical simulations for rapid growth of BH seeds via gas accretion in massive, metal-poor galaxies. Finally, I will discuss their impacts on the early establishment of BH-galaxy coevolution and the detectability of those rapidly growing seeds with the upcoming observations by the James Webb Space Telescope.

KEYWORDS

Division D

#607

Supermassive Black Holes and Merging Galaxies: Low-Frequency Gravitational Wave Detection with Pulsar Timing Arrays

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Observations have shown that nearly all galaxies harbor massive or supermassive black holes at their centers. Gravitational wave (GW) observations of these black holes will shed light on their growth and evolution, and the merger histories of galaxies. Pulsar timing arrays (PTAs) use observations of millisecond pulsars to detect low-frequency GWs with frequencies ~1-100 nHz, and can detect GWs emitted by supermassive black hole binaries, which form when two galaxies merge. In this talk, I will discuss the current status of the North American Nanohertz Observatory for Gravitational Waves (NANOGrav) PTA, with an emphasis on recent GW search results. The most recent NANOGrav search for a stochastic GW background found evidence for a common-spectrum process that may be the first hints of the stochastic gravitational wave background. Other regional pulsar timing arrays have found a similar common-spectrum process in their data sets, and a recently-published analysis by the International Pulsar Timing Array (IPTA) also found this common-spectrum process. I will discuss future prospects for detecting and characterizing the stochastic GW background from supermassive binary black holes as well as GWs from individual supermassive binary black holes.

KEYWORDS gravitational waves, pulsars, supermassive black holes

Division D

#2080

Results of optical research of selected active galactic nuclei

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Results of systematical monitoring of AGN BL Lacertae, 1ES 1011+496, PKS 1222+216, 1ES 1426+428, PKS 1510-089, Markarian 501 are presented. The observations were obtained during 2018-2021 using the telescope AZT-8 (D = 70 cm, F = 2.8 m) of the observation station Lisnyky of Astronomical Observatory of Taras Shevchenko National University of Kyiv. The AZT-8 is equipped with broadband Johnson/Bessel UBVRI filters and the PL4710-1-BB-E2V CCD (1027x1048 pixels, 13x13 µm/pixel, the scale is 0.95 "/pixel, the field of view is 16.2 angular minutes).

The fluxes of energy from the objects of research have been turned into visible stellar magnitudes with the help of standard stars. Light curves for objects BL Lacertae, 1ES 1011+496, PKS 1222+216, 1ES 1426+428, PKS 1510-089, Markarian 501 were plotted. We determined the amplitude of variability of brightness for all objects for Intraday variability, Short-term variability, and Long-term variability where it was possible. The variability of color indexes was investigated. The search of mechanisms of brightness change and the search of correlations between the optical and gamma ranges were also carried out.

KEYWORDS AGN, optical, monitoring, variability, UBVRI filters, brightness

e-Posters

Division D

#3319

Turbulent Magnetic Reconnection in Relativistic MHD Flows and the implications for particle acceleration and high energy phenomena

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Fast magnetic reconnection driven by turbulence is now recognized as an important process to accelerate particles in several astrophysical environments, especially in magnetically dominated regions of galactic and extra-galactic sources, like pulsars and black holes. This process helps to shed light on current puzzles related to the origin of very high energy (VHE) flare emission in relativistic sources. Here (Heinzen-Vicentin et al., in prep.), we have extended previous studies and performed high-resolution three-dimensional magnetohydrodynamical (MHD) simulations of relativistic current sheets in the presence of forced turbulence aiming at testing the predictions of the Lazarian and Vishniac (1999) theory in these extreme regimes. This theory, which has been thoroughly and successfully tested in non-relativistic flows, predicts that weak turbulence enhances the rate of reconnection by allowing many reconnection events to occur simultaneously, independent of Ohmic resistivity and determined by the magnetic field diffusion induced by the turbulence. We have tested the reconnection speed's dependence on the turbulent power and the energy injection scale in the relativistic flow, employing sophisticated techniques to measure this quantity from the simulations. Our results not only confirm the predictions of the Lazarian and Vishniac (1999) model, but also complement the results obtained by Kowal et al. 2009, considering different plasma-beta values, and confirm the recent results obtained from global simulations of magnetized relativistic jets of black holes (Kadowaki et al. 2021, Medina-Torrejon et al. 2021) where natural instabilities drove turbulence. Our results serve as a benchmark for any current studies on particle acceleration and the origin of VHE emission phenomena which are based on acceleration by reconnection.

KEYWORDS Magnetic Reconnection, Turbulence, Black Holes, Numerical Simulations, Relativistic MHD

Division D

#3142

Continuum Reverberation Mapping of high-luminosity AGN based on the Seoul National University AGN Monitoring Project (SAMP)

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The time delay (τ) between different optical continuum variations is found to be proportional to the size of the accretion disk and varies with wavelength as $\tau \propto \lambda^{4/3}$ as predicted by the standard accretion disk model. So, by finding the lags between different optical bands it is possible to constrain the accretion disk size in AGN. We started a long-term AGN monitoring project, namely Seoul National University AGN Monitoring Project (SAMP) since October 2015 using MDM 1.3m, MDM 2.4m, LOAO 1m, DOAO 1m and LCOGT 1m telescopes to study AGN variability and radius-luminosity relationship for high luminosity AGNs with luminosity ranges between 10^{44}-$10^{45.5}$erg/s at 5100 Å. The photometric observations are being carried out in optical B and V bands. In this poster, we present the preliminary continuum reverberation mapping results from our 6-year SAMP data for 32 targets in optical B and V bands along with ZTF light curve data in g, r and i-bands and MIR (W1, W2) from WISE. We will discuss on (i) lags between different optical bands (B, V, ZTF- g, r, i) to constrain the accretion disk sizes, (ii) consistency with standard accretion disk model from our results, (iii) constrain torus sizes by finding lags between optical and MIR(W1, W2) light curves, and also (iv) AGN flux as well as color variability properties and dependence of excess variance (F_{var}) on luminosity inferred from SAMP monitoring data.

KEYWORDS Galaxies, AGN, Quasars, Seyfert, Reverberation mapping, Photometry, Accretion disk

Division D

#3019

Phase resolved spectroscopic analysis of the eclipsing black hole high-mass X-ray binary M33 X-7

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High Mass X-ray binaries (HMXBs) with black hole companions represent a key intermediate step in the binary black hole formation channel. To understand the complex behavior of such systems, detailed knowledge of the massive donor is essential. However, only a few such systems are known so far. I will present a phase-resolved spectroscopic analysis of the extragalactic HMXB M33 X-7 using simultaneous XMM and HST observations. M33 X-7 is the only known eclipsing black hole binary with a very massive O-star and black holes known in HMXB systems. We performed a detailed spectroscopic analysis (Xray+UV+optical) at different orbital phases providing stellar and wind parameters of the metal-poor donor. I will discuss the detailed wind structure of the donor, wind accretion, and the impact of X-ray photoionization. Our new analysis suggests much lower masses for M33 X-7 and the donor is nearly filling its Roche lobe. The accretion luminosity derived using the Bondi-Hoyle calculation was found to be lower than the observed X-ray luminosity, possibly due to the deceleration of the wind by strong X-ray ionization. The observed properties are then compared with binary-evolution tracks to constrain the possible formation channel and evolutionary fate of the system.

KEYWORDS High Mass X-ray binaries, wind mass-loss, low metallicity, massive stars, Black hole, binary evolution

Division D

#2476

Sphericity and rotation of the universe and the Hubble's law

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Cosmologists have been acutely studying this mystery that universe is round or flat, because it's one that can tell us about the fundamental nature of the universe. In this paper we are going to proof that the universe is spherical and it has rotational motion by means of the Hubble's law. First, we assume that the universe is spherical. Of course, considering the Big Bang explosion at the beginning of the creation of the universe, the most probable, physical and logical form for the universe would be spherical. On the other hand, everything in the universe, from the smallest to the largest, is spherical, such as electrons, atoms, the moon, the earth, the sun, etc. So, it is very likely that the universe is also spherical too. By using this assumption, we wrote the equation for velocity of any object in the universe, which consists of two parts: a rotational part and a linear part.

Then, by comparing this equation with Hubble's law, we will conclude that the velocity which calculated by Hubble is the rotational part of this equation and this shows that the universe is spherical and rotating.

KEYWORDS Hubble's law, Universe shape, Big Bang

Astronomy for All
Busan 2022

Division D

#2150

The Strength of Field Equations as Indicator of Viability of Field Theories

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The problem of viability of field theories, represents one of the hard problems of the rival viable gravitational theories. Will (1980 and1981) put a set of six fundamental criteria for the viability of a gravitational field theory. It is found that there are many of them agree with general relativity in the weak field and strong field areas. Morcos (1992) suggested three more filtering criteria to differentiate between the rival viable theories. These filters are formation of large scale structures in cosmological models; minimizing the number of condition from outside the theory and compatibility & strength of field equations which had been suggested by Einstein (1955). The compatibility and strength method has been modified and simplified to have a simple expression for calculating the strength of the field equations for the required theory. The simplified expression has been used to compare between the strength of eight, 4 dimensional space-times. It is found that by increasing the strength numbers indicating the weakness of the field equations in treating the problem in this theory. This simple expression can be used not only for gravitational fields but also for other fields.

KEYWORDS Field Teories, Viability, Strength o Equations

Division D

#2122

Changing look activity of accreting black holes

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Some of the accreting black holes exhibit variability patterns different than stochastic variations. Radiation pressure instability is one of the proposed mechanisms which could account for this effect.
We model luminosity changes for objects with black hole of various mass using the time-dependent evolution of an accretion disk global model (using our code GLADIS). We explore the influence of the hot coronal flow above the cold disk, the inner purely hot flow, and the effect of magnetic field on the time evolution of disk-corona system. In the case of Intermediate Mass Black Holes and AGN we also explore the role of the disk outer radius, motivated by the fact that the disk may be fed by Tidal Disruption Events, or can be disrupted due to the companion binary black hole interactions.

We found that the outburst character strongly depends on the magnetic field strength and on the size of the disk.

We study various outburst patterns and apply our model to microquasars and their heartbeat states, to the rapid variability detected in Intermediate Mass Black Holes in the form of Quasi-Periodic Ejections, and to the Changing Look AGN phenomenon.

KEYWORDS accretion disks, X-rays, microquasars, AGN, Intermediate Mass Black Holes, variability

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Division D

#1002

Turbulent Magnetic Reconnection in Relativistic MHD Flows and the implications for particle acceleration and high energy phenomena

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Fast magnetic reconnection driven by turbulence is now recognized as an important process to accelerate particles in several astrophysical environments, especially in magnetically dominated regions of galactic and extra-galactic sources, like pulsars and black holes. This process helps to shed light on current puzzles related to the origin of very high energy (VHE) flare emission in relativistic sources. Here, we have extended on previous studies and performed high-resolution three-dimensional magnetohydrodynamical (MHD) simulations of relativistic current sheets in the presence of forced turbulence aiming at testing the predictions of the Lazarian & Vishniac theory in these extreme regimes. This theory, which has been thoroughly and successfully tested in non-relativistic flows, predicts that weak turbulence enhances the rate of reconnection by allowing many reconnection events to occur simultaneously, independent of Ohmic resistivity and determined by the magnetic field diffusion induced by the turbulence. We have here tested the dependence of the reconnection speed on the turbulent power and the energy injection scale in the relativistic flow, employing sophisticated techniques to measure this quantity from the simulations. Our results not only confirm the predictions of the Lazarian and Vishniac model, but also the recent results obtained from global simulations of magnetized relativistic jets of black holes (Kadowaki et al. 2021, Medina-Torrejon et al. 2021) where turbulence was driven by natural instabilities. Our results serve as a benchmark for any current studies on particle acceleration and the origin of VHE emission phenomena which are based on acceleration by reconnection.

KEYWORDS Magnetic Reconnection, Turbulence, Black Holes, Numerical Simulations

Division D

#951

Optimal Frequency Channelization for Pulsar Dispersion Measurements

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The precise determination of pulsar dispersion measure (DM) values is particularly important to the eventual detection of gravitational waves by pulsar timing arrays. In order to acquire the most accurate results, the uncertainty in the measured values of DM should be as low as possible. We investigate how the selection of the number of frequency channels affects the uncertainty in DM of pulsars used by the North American Nanohertz Observatory for Gravitational Waves (NANOGrav). This is done using the Pulsar Signal Simulator (Hazboun et al. 2021), which in addition to allowing the selection of number of frequency channels, also allows us to vary parameters such as the observed frequency, the telescope used for observation, and the specific pulsar. This simulated data gives us the ability to build a model which will give a baseline for the number of frequency channels that should be used depending on the observation type. This model will empower astronomers using data from existing and future radio telescopes to increase the quality of DM related research and contribute to the detection of low frequency gravitational waves.

KEYWORDS Pulsars, Dispersion Measure, Gravitational Waves

e-Talks

Division D

#3347

Measuring the masses and radii of neutron stars in LMXB and the constraints on the equation of state

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Low-mass X-ray binaries (LMXB) are composed of a compact object such as a neutron star accreting material from a donor star. During the accretion, thermonuclear burning can be induced on the surface of the neutron star and the Type-I X-ray bursts (XRBs) are emitted. From the observation of the XRBs, the physical properties of the neutron star can be estimated by Bayesian inference. Some Type-I XRBs exhibit photospheric radius expansion (PRE) and these PRE XRBs are used to simultaneously estimate the mass and the radius of a neutron star in LMXB. The estimation of the mass and the radius depends on the composition and the size of the photosphere.

In our research, we estimated masses and radii of neutron stars in 6 LMXBs exhibiting PRE XRBs by using Bayesian analysis. From the analysis results, we discuss the constraints on equation of state in the core of neutron stars. In order to clarify the effect of the equation of state, we reproduced the posteriors from our analysis by using 2 equations of states, KIDS and piece-wise polytropes. For the comparison, we reproduced the posteriors of EoS parameters inferred from GW170817 observed by LIGO and Virgo gravitational wave detectors, and PSR J0030+0451 and PSR J0740+6620 from NICER X-ray observations.

In conclusion, we discuss the constraints on the equation of state inferred from the combining results of multiple observations.

KEYWORDS neutron star, equation of state, x-ray burst, LMXB, GW170817, J0030+0451, J0740+6620

Division D

#3276

Tidal disruption event of a white dwarf by a black hole. Quantum hydrodynamics simulations

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We study the final stages of the evolution of a binary system consisting of a black hole and a white dwarf star. As a model of a white dwarf star, we consider a Bose-Fermi droplet at zero temperature of attractively interacting degenerate atomic bosons and spin-polarized atomic fermions. We implement the full quantum hydrodynamic equations and carry out numerical simulations to follow the evolution of the binary system. While going through the periastron, the white dwarf loses a fraction of its mass. Due to nonlinear effects, the accretion disk originated from the white dwarf becomes fragmented. Additionally, quantized vortices present in the bosonic component of the accretion disk are observed. We also investigate electromagnetic and gravitational radiation generated during a process of the tidal stripping of a white dwarf. The falling mass is a source of powerful electromagnetic radiation. Bursts of ultraluminous radiation are flared at each periastron passage by a white dwarf. This resembles the recurrent flaring of X-ray sources.

KEYWORDS white dwarfs, binaries, tidal disruption event, quantum hydrodynamics, computer simulations, quantum vortex, electromagnetic radiation

Division D

#2671

Gravitational-wave EM Counterpart Korean Observatory (GECKO) and 7-Dimensional Telescope for Follow-up Observation of Gravitational-wave Sources

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The 2017 detection of the binary neutron star (BNS) merger event in both gravitational wave (GW) and electromagnetic wave (EM), GW170817, has shown the great potential for multi-messenger astronomy, allowing us to understand the link between neutron star mergers and gamma-ray bursts, physical mechanisms and environments of the EM counterpart, kilonova (KN), and cosmology with GW sources. Yet, GW170817 is still the only GW event for which MMA was possible. However, with the scheduled start of the O4 run in December 2022, the situation will soon change. The forecast is about 10 BNS merger event detections during O4, with many of them having a GW localization accuracy on par with GW170817. To capitalize on the anticipated GW source discoveries, we have been preparing an optical EM follow-up network of telescopes, named the Gravitational-wave EM Counterpart Korean Observatory (GECKO). We will outline the current challenges of optical/NIR counterpart observations for the KNe discovery, and outline GECKO and our past activities. In particular, we will focus on our observation program with KMTNet, a system of three, 1.6-m wide-field telescopes in the southern hemisphere, and a new facility in construction, the 7-Dimensional Telescope (7DT). 7DT is a multiple-telescope system that can perform a spectral mapping over a wide field of view (> 1 deg2) and will be efficient in catching KNe associated with future GW events. Our activity includes the application of the artificial intelligence technique for identifying KNe rapidly. A partial system of 7DT is expected to start its operation in late 2022.

KEYWORDS Multi-Messenger Astronomy, Binary Neutron Star Meger, Gravitational-wave Source, Multiple Telescope System, Kilonova, GW Source Host Galaxy, Black Hole Merger

Division D

#1698

Observing Black Holes and Neutron Stars Throughout Time with Cosmic Explorer

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Albert Einstein predicted gravitational waves in 1916, as a consequence of his general relativity theory. A century later, the Laser Interferometer Gravitational-Wave Observatory (LIGO) in the US and Virgo in Europe began observing these waves from merging systems of black holes and neutron stars. These observations cemented relativity theory and inaugurated an era of gravitational-wave multi-messenger astronomy.

Cosmic Explorer (CE) is a next-generation ground-based gravitational-wave observatory envisioned to begin operations in the 2030s. With its spectacular sensitivity, CE will peer deeply into the universe's dark side — observing black hole and neutron star systems from the first stars and nearer-by systems with signal to noise in the thousands — while also opening a wide discovery aperture to the novel and unknown.

The observational science possible with CE, and the planned European sister observatory Einstein Telescope, will be sketched, along with the key technologies and instrument science targeted for Cosmic Explorer.

KEYWORDS Gravitational waves, Neutron Stars, Black Holes, Observatories, Interferometery

Division D

#1503

The irradiated disk spectrum emitted from a spinning supermassive black hole

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We study the irradiated disk spectrum of an accretion disk around a spinning supermassive black hole (SMBH). Soft-X-ray emission from the inner edge of the accretion disk around the SMBH irradiates the outer part of the disk. The irradiation heating enhances the disk flux at a lower frequency so that the resultant disk spectrum deviates from the multi-color blackbody spectrum of the standard disk. We find the irradiated disk spectrum shows a clear double peak due to the irradiation heating. In the case of the extreme Kerr black hole, the spectrum is more luminous than that of the non-spinning black hole over the almost entire range of the frequency. We show how black hole mass, spin, and disk temperature profile contribute to the double peak nature. We also discuss the observational implications of our model.

KEYWORDS accretion disk, disk spectrum, supermassive black hole, black hole spin, irradiation

Division D

#1394

Relativistic model for an advective accretion disk in tidal disruption events

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Tidal disruption events (TDEs) provide a good probe for quiescent supermassive black holes (SMBHs) in the centers of inactive galaxies. A star is tidally disrupted by an SMBH when the star approaches the SMBH closely enough that the black hole's tidal force exceeds the stellar self-gravity. The subsequent super-Eddington accretion of stellar debris falling onto the SMBH produces a characteristic flare lasting several months. In the TDE context, we develop a new steady-state solution for general relativistic (GR) super-Eddington accretion flows in the radiation pressure dominated regime, where the angular momentum loss due to the radiation and contribution of the scale-height derivative should play an important role in an advection energy loss. We find that the surface density and temperature of the disc near the inner edge decreases because of the angular momentum loss due to radiation, resulting in a decline in the disk luminosity. Notably, the surface density and temperature are anti-correlated with the mass accretion rate. This result shows the opposite tendency of some previous works that have been done so far. Applying our model to the TDE observations, we estimate the black hole spin parameter for a given black hole mass and stellar mass.

KEYWORDS Tidal disruption events, accretion disks, quasars: supermassive black holes, general relativistic process

Division D

#1301

Tidal disruption event of a white dwarf by a black hole. Quantum hydrodynamics simulations.

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We study the final stages of the evolution of a binary system consisting of a black hole and a white dwarf star. As a model of a white dwarf star, we consider a Bose-Fermi droplet at zero temperature of attractively interacting degenerate atomic bosons and spin-polarized atomic fermions. We implement the full quantum hydrodynamic equations and carry out numerical simulations to follow the evolution of the binary system. While going through the periastron, the white dwarf loses a fraction of its mass. Due to nonlinear effects, the accretion disk originated from the white dwarf becomes fragmented. Additionally, quantized vortices present in the bosonic component of the accretion disk are observed. We also investigate electromagnetic and gravitational radiation generated during a process of the tidal stripping of a white dwarf. The falling mass is a source of powerful electromagnetic radiation. Bursts of ultraluminous radiation are flared at each periastron passage by a white dwarf. This resembles the recurrent flaring of X-ray sources.

KEYWORDS white dwarfs, binaries, tidal disruption event, quantum hydrodynamics, quantum vortex, electromagnetic radiation, gravitational radiation

Division D

#1099

BLR Stratification and Hα Size-Hα Luminosity Relation

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The size-luminosity relation of the broad line region (BLR) has been a paramount tool in determining the mass of active galactic nuclei (AGNs). Traditionally, the optical continuum luminosity at 5100Å has been used to estimate the size of Hβ BLR. However, the continuum luminosity suffers from stellar emission contamination, rendering this method less reliable without high-resolution images to resolve the host galaxy. The luminosity of Hα BLR, which does not suffer from a similar issue, has been used as well to estimate the stellar-free continuum luminosity. Nevertheless, this relies on the assumption that Hα and Hβ BLRs share the same size. We investigated the sizes of Hα BLR of 43 AGNs, including 5 we newly measured. We found that the size of the Hβ BLR is consistently smaller than that of Hα, and the relation between them deviates from linear relation. Furthermore, we established a correlation between the size of Hα BLR and its luminosity directly. This relation will provide a useful tool to investigate fainter and more distant AGNs, particularly for finding intermediate-mass black holes.

KEYWORDS Active Galactic Nuclei, Broad Line Region, Reverberation Mapping

Division D
#917

GECKO: Follow-up observation of GW190425 and prospects for early detection of kilonovae in O4 run

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Recent observation of the binary neutron star (BNS) merger event, GW170817, through both gravitational wave (GW) and electromagnetic wave (EM) opened a new way of exploring the universe, namely, multi-messenger astronomy (MMA). One of the keys to the success of MMA is a rapid identification of its EM counterpart, kilonova (KN). Despite the importance, it is hard to find a fast decaying KN associated with a GW event, due to a poorly constrained GW localization map. Not only that, GW events can occur at coordinates where telescopes cannot observe immediately. Therefore, a network of telescopes all around the world has a great merit to follow up GW events fast, and an efficient follow-up strategy is essential. In this talk, we introduce the Gravitational wave Electromagnetic wave Counterpart Korean Observatory (GECKO) project, our strategy for prioritization of GW source host galaxy candidates, and future prospects of GECKO in LIGO/Virgo observing run 4 (O4). GECKO is a network of more than ten telescopes at different longitudes and latitudes. To make efficient follow-up, we assign a score to each galaxy in the localization area based on the galaxy properties, and use the prioritized list of galaxies to search for KN. Armed with this strategy, we performed optical/NIR follow-up observation of GW190425, the first BNS merger event during O3. Despite a very wide localization area of 7460deg2, we were able to observe 621 host galaxy candidates, corresponding to 29.5% of the scores we assigned, with most of them observed within the first 3 days of the GW event. We will show transients discovered during this search, including an unreported transient with the host galaxy. We also discuss combined results with other EM follow-up campaign with wide-field of view instruments, GROWTH, which covered most of GW localization map at the northern hemispheres, emphasizing the global effort of GW MMA. The GECKO observation demonstrates that GECKO can possibly uncover a GW170817-like KN at a distance<200Mpc, if the localization area is less than 1100deg2 or so. With many GECKO facilities all around the world, we expect an early detection of GW EM counterparts in the upcoming O4.

KEYWORDS gravitational waves, galaxies, kilonovae

Division D

#905

Constraints on the Progenitor System of A Type Ia Supernova 2021hpr from the Early-Time Excess Emission in the Light Curve

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The progenitor system of Type Ia supernovae (SNe Ia) is largely expected as a binary system of a carbon/oxygen white dwarf and its non-degenerate (Single degenerate model; SD) or degenerate companion (Double degenerate model; DD). However, it is still uncertain which model is prevalent in observation. Motivated by this, we present the early-time observation result of SN 2021hpr, a Type Ia supernova in a spiral galaxy, NGC 3147 from our high-cadence monitoring data. SN 2021hpr is close to a normal SN Ia from the photometry (decline rate in B-band dm15(B)=1.01+/-0.03, dust-free MB,max=-19.45+/-0.02) and spectroscopy. We found a significant feature of a bluish early-time excess emission on the light curve. We fit the early part of BVRI-band light curves simultaneously with a combined version of the ejecta-companion interaction and the simple power-law model. The fitting result gives us the companion radius of 7.60+/-0.57 Rsun assuming the optimal viewing angle. In the HST pre-explosion imaging, we found no possible progenitor candidates at the position of the supernova but the detection limit excludes massive stars with the initial mass Minit>16 Msun. In addition, we could not detect the significant H-alpha emission resulting from the stripped mass of H-rich matter of companion predicted in the SD model from the late-time (>200 days since the explosion) low-resolution spectrum. We discuss the possible progenitor system of SN 2021hpr as (i) an SD channel with little H-alpha emission or (ii) other channels (Double detonation, Disk-Originated Matter interaction).

KEYWORDS supernovae:general, supernovae: individual (SN 39 2021hpr), galaxies: distances and redshifts, methods: observational

Division D

#805

Tidal Stripping of a White Dwarf by an Intermediate-Mass Black Hole

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White dwarf (WD) inspiralling into an intermediate-mass black hole (IMBH, Mh ~ 102-5 Msun) in an eccentric orbit (e ~ 0.7 - 0.9) can be observed by both of the gravitational waves (GWs) and electromagnetic (EM) radiation. When the pericenter radius is slightly larger than the tidal radius, the WD would be tidally stripped during each pericenter passage, and the accretion of these stripped mass would produce EM radiation. It is suspected that the quasi-periodic eruptions (QPEs), which are discovered by the X-ray telescopes in recent years, might originate from such system. Modeling these flares requires an prediction of the stripped mass of the WD and how these masses supply to the accretion disk. The goal of this work is studying the orbital parameter dependencies of the stripped mass and the corresponding mass fallback rate through hydrodynamical simulation. Based on these results, we further calculate the mass-loss evolution of the WD during its inspiral and investigate the detectability of the GW and EM signals. We find that the EM signal from the mass-loss stage can be easily detected: the limiting distance is ~ 323(Mh/104 Msun) Mpc for the Einstein Probe (EP), which is scheduled to be launched by the end of 2022. And the GW detectable horizon distance is much smaller, which is ~ 14(Mh/104 Msun)7/15 Mpc for the next-generation GW detectors, e.g., Laser Interferometer Space Antenna (LISA) and TianQin. Those WD-IMBH inspirals with large WDs (~ 1 Msun) will be the ideal targets for the GW detection.

KEYWORDS accretion, accretion disks, black hole physics, galaxies: nuclei, tidal disruption

DIVISION E
Sun and Heliosphere

Invited & Contributed Talks

Division E

#1788

Predicting the Solar Cycle: Where do we stand?

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The Sun's magnetic cycle, sustained by a magnetohydrodynamic dynamo mechanism in its interior, modulates the electromagnetic, particulate, and radiative environment in space. While transient, energetic events such as flares and coronal mass ejections generate severe space weather, slow long-term solar activity fluctuations modulate space climate. Space weather impacts space-reliant technologies that sustain our modern society, while space climate influences planetary atmospheres and climate. The ability to predict sunspot cycles is therefore a much sought after goal in Heliophysics. Solar cycle predictions, however, has remained an outstanding challenge for the space science community. In this review, I shall critically assess the field of solar cycle predictions and demonstrate that while predictions based on diverse techniques disagree across solar cycles 24-25, physics-based predictions for solar cycle 25 have converged and indicates a weak to moderate sunspot cycle. Based upon our own theoretical work as well as long-term solar cycle observations, I shall argue that this convergence is indicative of progress in the fundamental understanding of solar cycle predictability. Building upon this understanding, resolutions to several outstanding questions related to solar cycle predictions will be discussed.

KEYWORDS Sun, Sunspot, Solar Cycle, Solar Dynamo, Solar Cycle Predictions, MHD, Space Weather

Division E

#740

The solar atmosphere at small scales: loops and associated dynamic phenomena

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Small-scale loops are one of the main building blocks of the solar atmosphere outside active regions. Some of those are commonly referred to as coronal bright points for historical reasons. They dominate the solar corona when seen in extreme-ultraviolet (EUV), especially during the solar activity minimum, and are also found in polar and equatorial coronal holes. Their role in the heating of the upper solar atmosphere is still highly intriguing and under debate. I will review their main morphological, magnetic, and plasma properties reported in studies that span more than five decades. The evolution of these small-scale loops has often been related to dynamic solar phenomena that are observed throughout the solar atmosphere. I will review the small-scale loops' relation to chromospheric phenomena including surges, spicules/mottles, macrospicules, Halpha small-scale loops, etc. Their role in the formation of mini-filaments and their interplay in small-scale eruptions such as mini-coronal mass ejection and EUV and X-ray jets will be discussed. My review talk will conclude with discussing the possible role of small-scale loops, their formation and evolution, in the heating of the solar atmosphere and the imprint of their associated transient phenomena on the solar wind.

KEYWORDS Sun, Solar atmosphere, Loops, Transients, Coronal heating, Solar wind

Division E

#2739

Diagnostic potential of Hε for small-scale energetic phenomena

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The Hydrogen Balmer lines show enhanced emission in various energetic phenomena in the solar atmosphere. For example, the Hα line shows complex wing enhancements in the Ellerman Bomb phenomenon. Recently, Ellerman bombs have been detected in the Hβ line at high number densities in the Quiet Sun and it was concluded that these mark the ubiquitous presence of small-scale magnetic reconnection. In this work, we explore the diagnostic potential of the Hε line, one of the shorter wavelength Balmer lines that promise detection of small-scale energetic events at higher spatial resolution than achieved before. Hε is located just redward of the strong Ca H line core which poses a challenge for the understanding of the spectral line formation. To understand the formation of Hε, especially the transition from absorption to emission line, we investigate the line formation using 3D radiative MHD Bifrost simulations and NLTE forward modelling with RH. The locations where Hε goes into emission mark regions of lower chromospheric temperature enhancements and indicate regions where magnetic energy is released, heating the solar atmosphere. Hε could be therefore a valuable tracer for small-scale energetic events in the solar atmosphere.

KEYWORDS Sun: chromosphere, radiative transfer, magnetic reconnection, lines: formation

Division E
#2479

Quiescent prominence diagnostics based on ALMA, UV and H-alpha/ MSDP observations

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Solar prominences are commonly observed above solar limb for more than a century. Development of new observing techniques allow us to detect them not only during solar eclipses but anytime and in different spectral bands - from radio to far-UV. The radio data in the millimeter range offer a unique possibility to analyse independently the kinetic temperature of the prominence plasma. However, past studies used observations with low spatial resolution, insufficient to resolve prominence fine structures.

Recently, ALMA interferometer observed a few prominences in millimeter wavelengths with good spatial resolution, comparable to the ground-based optical observations. In our work we use the new data obtained at 3 millimeters during the coordinated space and ground-based observing campaign. For the first time high-resolution observations of the fine prominence structures in the millimeter radio domain are available. In addition, this prominence was also observed in the UV with IRIS and in the H-alpha line with the MSDP imaging spectrograph of the Wroclaw Observatory. These data contain not only images, but also spectra which allow us to diagnose the prominence plasma, in particular, to obtain its kinetic temperature. Moreover, all UV, H-alpha and ALMA observations are co-temporal which gives an unprecedented opportunity for a novel diagnostic, not available so far.

In this work we use multi-wavelength combined data for the analysis of the statistical dependences between various parameters characterising the emitting plasma. In addition, UV and H-alpha data are compared with the brightness temperature derived from ALMA, providing an additional information on the plasma parameters, in particular the kinetic temperature. Here we report preliminary results of our analysis.

KEYWORDS Sun: prominences, imaging spectroscopy, numerical methods, interferometry

Division E

#725

Solar Lyman-alpha and Mg II h&k radiation variability with the solar cycle and its impact on the diagnostics of chromospheric and coronal structures

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The solar radiation in the Lyman-alpha and Mg II h&k spectral lines plays a crucial role in the illumination of chromospheric and coronal structures, such as prominences/filaments, spicules, chromospheric fibrils, cores of coronal mass ejections, or solar wind. Moreover, it is important for the investigation of the heliosphere, Earth ionosphere, and the atmospheres of planets, moons, and comets.

However, the radiation from the solar disk is not constant in these lines but changes considerably throughout the solar cycle. To study these changes and their impact, we first had to set the baseline representing the radiation from the solar disk during a minimum of solar activity. We thus derived new sets of quiet-Sun reference profiles of Lyman-alpha and Mg II h&k lines. For the Lyman-alpha line, we used SOHO/SUMER raster scans obtained without the use of the SUMER attenuator (Gunár et al. 2020) and for the Mg II h&k lines we used the broad catalogue of IRIS full-Sun mosaics (Gunár et al. 2021). To quantify the variability with the solar cycle, we used the LISIRD Composite Lyman-alpha index to adapt the Lyman lines to any specific date (Gunár et al. 2020). For the Mg II h&k lines, we used a data-driven model based on the Bremen Composite Mg II index (Koza et al. 2022). These long-term measures then allowed us to investigate how the changing irradiation from the solar surface influences the synthetic spectra produced by the radiative transfer modelling. As we showed in Gunár et al. (2020, 2022), both changes in the Lyman lines and the Mg II h&k lines affect the resulting synthetic spectra significantly, even up to 50 % depending on the strength of individual solar cycles. That, however, has a strong impact on the diagnostics of the observed chromospheric and coronal structures, making up-to-date information about the solar activity a critical input for their precise modelling.

KEYWORDS Solar ultraviolet emission, Solar cycle, Solar prominences, Radiative transfer modelling

Division E

#2420

Modeling of Solar Magnetic Phenomena: Past, Present, and Future

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The magnetic nature of the Sun is reprsented by various solar magnetic phenomena, such as the solar cycle, solar flares, solar winds, and coronal mass ejections. In this talk I discuss three types of models used for investigating these phenomena, that is, idealized model, realistic model, and predictive model.

The first model has the longest history among them, which is focused on clarifying a fundamental physical mechanism and/or process opeating in a solar magnetic phenomeonon. The model relies on analytical methods and/or numerical simulation, to explain one or several observational features derived from actual events that belong to the phenomenon. Since these events genearally have a lot of complexity, how to idealize their structure and evolution is a key in this model.

The second and third models may fall into a category of high-performance computational models, which has recently emerged as the speed and capability of computers increase. In contrast to the first model, their focus is on the complexity that actual events have. Recent developments in computer technology encourage us to reproduce realistic evolution of such an event and predict its evolution.

I will start my talk by overviewing a history of the idealized model and then explain the present status of research using the three models. I will also talk about futre solar modeling research.

KEYWORDS

Division E

#2722

Observational features of solar filaments and their implications

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Solar filaments, also called solar prominences, are cold and dense plasma suspended in the hot and tenuous corona. Filaments are elongated structures, with a few barbs extending away from the main spine. They are suppported by sheared and/or twisted coronal magnetic field above polarity inversion lines, which are indicative of non-potential magnetic field, hence solar filaments are intimately related to solar flares and coronal mass ejections (CMEs). With high-resolution observations, it has been revealed that solar filaments consist of many threads, which are always dynamic, forming counterstreamings. All these observational features, including their morphology and rich dynamics, provide a unique pathway for us to decipher their otherwise unmeasurable magnetic topology, which is crucial for their eruptions. In this talk, I will give a review on the typical morphology and dynamics of solar filaments and attempt to explicate their implications for the magnetic structures.

KEYWORDS solar filaments, solar prominences, magnetic field, oscillations, eruptions, solar flares

Astronomy for All
Busan 2022

Division E
#1985

Plasma characteristics during microflares from combined STIX-STEREO observations and hydrodynamical modeling

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After the launch of the Spectrometer Telescope for Imaging X-rays (STIX) onboard Solar Orbiter on 10 February 2020, it is recording solar X-rays uninterruptedly since January 2021 covering the rising phase of solar cycle 25. STIX registers X-rays in 4-150 keV energy range with a time cadence as high as 0.1 s. Moreover, thirty pixelated detectors allow the reconstruction of spatial distribution (images) of solar X-ray sources. The observing line-of-sight of STIX and STEREO-A satellites remained in close vicinity during September 2021, thus offering a unique opportunity for a detailed multi-instrument investigation of active region behavior during solar flares. Therefore, we selected several microflares in this duration, observed simultaneously by STIX, STEREO-A as well as SDO satellites. By analyzing the STIX lightcurves, spectra, and images, we determined the thermal and non-thermal nature of flare plasma producing microflares (e.g. temperature, emission measure, and non-thermal spectral index). In addition, the reconstructed images were employed to estimate the volume of sources (eventually density) of the emitting regions. These parameters were used for constructing the diagnostic diagrams (density-temperature relation) which we compared with that obtained from 1-d hydrodynamical simulations (Palermo-Harvard code). A comprehensive thermal characteristic of the flare plasma is obtained by deriving DEM over a wide range of temperatures covered by observational data. Obtained results show that STIX is providing crucial information about hot plasma in solar microflares allowing for the investigation of physical properties of microflares and their comparison with the large scale flares occurring in the same region.

KEYWORDS Sun, Microflares, X-rays, EUV, HD simulations, STIX

Division E

#1385

On the evolution of magnetic helicity flux from solar active regions: Our present understanding

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Magnetic helicity is a parameter to quantify twist and shear of magnetic field and is related to formation of flux rope structure. Understanding the nature and evolution of the photospheric helicity flux transfer is crucial to reveal the role of magnetic helicity in coronal dynamics of solar active regions (ARs). The estimations of magnetic energy and helicity flux from a line-tied surface (photosphere) requires velocity and magnetic field distributions in the AR. In this presentation, we will discuss the helicity flux evolution from different active regions and then understand the relation to the eruptive or transient activity from that AR.

KEYWORDS magnetic field, magnetic helicity, coronal mass ejections, flares, magnetic reconnection, active retions, Sun

Division E

#1547

Evolution of magnetic fields and energy release processes during homologous eruptive flares

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Understanding the mechanism for the formation of magnetic flux rope in solar active regions and identification of instabilities that lead to their subsequent eruption are among the most crucial topics of research in contemporary solar physics. With this objective, we explore the build-up and energy processes of three homologous eruptive flares of successively increasing intensities (i.e., M2.0, M2.6, and X1.0). The flares originated from the leading sunspot group of active region NOAA 12017 during 2014 March 28–29 within an interval of ≈24 hr. Nonlinear force-free field (NLFFF) modelling of the active region corona reveals a magnetic flux rope along the polarity inversion line in the compact flaring region which is observationally manifested by the co-spatial structure of an active region filament. With each eruptive flare, the MFR and overlying closed bipolar loops undergo blowout-eruption with corresponding CME. We conduct detailed investigation of large- and small-scale changes in the photospheric magnetic fields over an interval of ≈44 hr. We note that the photospheric magnetic field undergoes drastic changes from events I to III with prominent phases of flux emergence and cancellation. Importantly, significant changes in the magnetic field distribution are observed near the polarity inversion line, providing support for tether cutting mechanism toward repetitive build-up of magnetic flux rope. The RHESSI X-ray spectroscopic analysis reveals an increasing dominance of non-thermal emission as the flaring intensity increases from events I to III. Our study shows a good agreement between the magnetic flux emergence through the photosphere and storage of magnetic energy in the active region corona.

KEYWORDS

Division E

#2821

Recent Instrumentation: Science and Status

Valentin Martinez Pillet[1]

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I will review in this talk the ground and space-based instrumentation that is starting to produce data following the commissioning phase, emphasizing the Daniel K Inouye Solar Telescope (DKIST) and Solar Orbiter. The ability to observe the Corona with DKIST and Solar Orbiter simultaneously represents an opportunity to understand the in-situ consequences of the processes observed in the solar atmosphere with unprecedented detail and sensitivity.

The next natural step for the National Solar Observatory is to strengthen our regular monitoring of the global Sun by renewing our synoptic facilities. In collaboration with the broader US and international community, NSO is proposing a next-generation GONG network that incorporates from inception space weather requirements. I will briefly describe the current situation of the ngGONG project.

KEYWORDS Sun, Instrumentation, DKIST, ngGONG

Division E

#2814

A Whirlwind Tour of the Corona-Solar Wind Connection: Science and Status

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Recent years have brought about a revolution in heliophysics, with an unmatched variety of measurements now available. These measurements are taken in new locations throughout the heliosphere, use new measurement techniques, and employ new types of instrumentation. This has led to new discoveries directly, such as solar wind switchbacks, while also enabling a different type of discovery: connection science. We are now entering an era where it is possible to link together remote and in situ observations, unveiling a new understanding of how the solar corona connects to the solar wind and heliosphere. Here we give an overview of recent exciting space-based missions and survey their discoveries, and discuss the connection science they enable.

KEYWORDS sun, heliosphere, solar wind

Division E

#461

The Science of PUNCH

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The Polarimeter to Unify the Corona and Heliosphere, or PUNCH, is a Small Explorer Mission selected by NASA for flight. PUNCH providas a full field of view from pole to pole via four synchronous smallsats, filling existing gaps between coronagraphs and heliospheric imagers. PUNCH's goal is to comprehend cross-scale physical processes of heliophysics, from micro scale turbulence to the evolution of global scale structures. With PUNCH, we can answer questions about the the quiescent solar wind (to what degree are mesocale structures solar in origin vs developing en route? what are the implications for turbulence?) and in the transient solar wind (How do the classic CME substructures of front, cavity and core evolve in the solar wind -- do they deform, decay, deflect? What is the 3D morphology and internal structure of stream interaction regions -- how do they form, how do they evolve?) It will also map the frothy Alfven zone that is the interface between corona and heliosphere, and observe the formation and evolution of shocks across spatial scales. In this talk we describe the methodologies being developed -- and tested -- in advance of PUNCH's launch. In particular, we provide highlights of ongoing work to develop analysis tools for flow mapping, polarization diagnostics, forward modeling, and tomography.

KEYWORDS sun, solar wind

Division E

#717

Science Objectives of Aditya-L1

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In order to fully comprehend the dynamics of the solar atmosphere and its impact on the heliosphere, it is imperative to perform multiwavelength remote sensing studies including in-situ measurements. The Aditya-L1 is the first observatory, scheduled to be launched in late 2022, of the Indian Space Research Organization (ISRO) in space dedicated to solar observations. The spacecraft will carry seven payloads providing uninterrupted observations of the Sun using remote sensing and in-situ measurements from the first Lagrangian point. There are four remote sensing instruments: a coronagraph, a full-disk near-ultraviolet (NUV) imager, and full-sun integrated soft X-ray and hard X-ray spectrometers. In addition, there are three instruments, including a magnetometer, to study the solar wind and interplanetary magnetic field variations during energetic events. For the first time, the Aditya-L1 mission aims to provide the coronal magnetic field measurements from space and spatially resolved solar spectral irradiance in NUV, which is central to the Sun-climate relations. This talk will highlight some of the salient features of the mission and the crucial roles it will play in enhancing our knowledge in the science of the solar atmosphere and heliosphere.

KEYWORDS

Division E

#2840

Understanding the behavior of the Sun's large scale magnetic field and its relation with the meridional flow

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In this thesis talk, I will be presenting various studies that are performed to a better understanding of the 11-year solar cycle and its theoretical modeling with the flux transport dynamo (FTD) models. I will start by explaining how magnetic buoyancy has been treated in the flux transport dynamo models and the advantages and disadvantages of different treatments. It is found that some of the irregular properties of the solar cycle in the decaying phase can only be well explained using a particular treatment of magnetic buoyancy. Next, the behavior of the dynamo with different spatial structures of the meridional flow based on recent helioseismology results will be discussed. I will also explain a theoretical model that is constructed considering the back reaction due to the Lorentz force on the meridional flows which explains the observed variation of the meridional flow with the solar cycle. Finally, some results with 3D FTD models will be discussed. This 3D model is developed to handle the Babcock-Leighton mechanism and magnetic buoyancy more realistically than previous 2D models and can capture some important effects connected with the subduction of the magnetic field in polar regions, which are missed in 2D surface flux transport models. This 3D model is further used to study the evolution of the magnetic fields due to a turbulent non-axisymmetric velocity field and compare it with the results obtained by using a simple turbulent diffusivity coefficient.

KEYWORDS solar dynamo, meridional circulation, magnetic buoyancy

Division E

#3116

On the Dynamics of Spicules and Mass-Flows in the Solar Atmosphere

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The atmosphere of the Sun is envisioned as composed of inherently complex, non-homogeneous, and dynamic layers. A detailed understanding of the physical processes involved in these layers is still lacking. For example, it is largely unknown why the outermost layer of the Sun's atmosphere (the solar corona) is so much hotter than the photosphere by millions of degrees. Astrophysicists think that the layer sandwiched between the photosphere and the corona, known as the interface region, may hold the key to a better understanding of the nature of this enigma. With the help of coordinated high-resolution, ground- and space-based observations from the Swedish 1-m Solar Telescope (SST) on La Palma, Spain, and NASA's Interface Region Imaging Spectrograph (IRIS) and Solar Dynamics Observatory (SDO), along with the support from an advanced numerical simulation, I aim to unlock some of the mysteries surrounding the dynamics of the interface region with a focus on small-scale jets, known as "spicules". Spicules are found almost everywhere on the Sun's surface and at any given moment there can be as many as 10 million of them rapidly shooting outwards. They are often found to be heated beyond chromospheric temperatures and appear in the transition region and (even) coronal passbands. Because of their "omnipresence", it is suggested that they play a major role in energizing the outer atmospheric layers of the Sun. This thesis focuses on the physical characteristics and dynamics of spicules, along with their role in mass-balance and heating of the solar atmosphere.

KEYWORDS

Division E

#3117

Study of Solar Jets and Related Flares

Reetika Joshi[1]

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Solar jets are ubiquitous transient collimated mass outflows in the solar atmosphere over a wide range of sizes from small scale nanojets to a few solar radii, embedded in the solar chromosphere to solar corona. Jets are frequently accompanied by solar flares and these flares provide the force to propagate the plasma material upward and could be accompanied by coronal mass ejections. These jets could act as a source for transporting a significant mass and energy from the lower solar atmosphere to the upper coronal heights and consequently heating the solar corona and accelerating the solar wind. Magnetic reconnection is believed to be the triggering reason behind these small scale jet activities. The thesis entitled “Study of Solar Jets and Related Flares” includes various case studies with different mechanisms to set off the jet initiation, associated large scale eruptions and mounts strong observational evidences to validate the numerical experiments for the magnetic flux emergence models. Such studies on solar jets along with their magnetic origin contribute to resolve the scandalous coronal heating problem and provide the evidences for the existing theoretical models and open a new window for the interplanetary science.

KEYWORDS

Division E

#1764

Data Constrained Models for Solar Activity Predictions

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With the advancement of human civilisation, we are becoming more inclined towards space-based technologies. However, our satellites, GPS, telecommunication systems are exposed to persistent dangers caused by the changing environment in outer space, the origin of which is closely associated with the Sun. Like many other active stars, the Sun is a plasma body where complex physical processes lead to the generation and destruction of strong magnetic field. The modulation in the field subsequently controls the electromagnetic, radiative and particulate output of the Sun, creating weather in space. Thus, scientific studies aiming to predict the variation of solar magnetic activity has gained a significant impetus in recent times; the same has been a major motivation for the research performed in this thesis.

Through utilising a newly developed observational data-driven computational model along with two other existing models, we present predictions of the space weather and space climate in the next decade. Moreover, our work successfully reproduces the past solar activity during the last century and provides a physical explanation of the distinct characteristics observed in the Sun. Altogether the thesis work imparts a deeper understanding of the complex processes within the Sun and in other stars.

KEYWORDS Sun, Magnetic field, Dynamo, Cycle 25, Prediction

Division E

#325

Evolution of Interplanetary Coronal Mass Ejections and their Space Weather Impact throughout the Inner Heliosphere: a Modeling Perspective

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Interplanetary coronal mass ejections (ICMEs) are among the largest and most energetic transients in the heliosphere, where they shape the conditions of the space environment and can drive severe space weather disturbances at Earth and other planets. Yet, our knowledge about their three-dimensional structure and ever-changing nature in response to interactions with other large-scale structures in interplanetary space (including, e.g., high-speed solar wind streams, stream interaction regions, and other ICMEs) is incomplete, and further complicates our prediction of their space weather impact.

In this talk, I will summarize recent advances in our understanding of ICME evolution obtained from numerical simulations employing the EUHFORIA model. I will discuss how novel approaches in the analysis of simulation outputs can complement the scarcity of observational data, and help us in tackling some prominent open questions regarding the evolution of ICME magnetic structures during propagation. Particular attention will be devoted to the role of interactions with other interplanetary structures in altering the magnetic complexity of ICMEs, their potential space weather impact, and their ability to behave as magnetically coherent structures.

KEYWORDS Coronal Mass Ejections, Solar wind, Magnetohydrodynamics

Division E

#1865

Three-dimensional simulation of the fast solar wind: the role of parametric decay instability

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How the solar wind is heated and accelerated is an important unsolved problem in astrophysics. While the opening of the closed magnetic loop (interchange reconnection) is likely to play a role in the active-region outflow and intermittent slow solar wind, Alfven waves and turbulence are believed to drive the fast solar wind from the polar coronal hole. Based on the fact that the fast solar wind is nearly non-compressional, this wave/turbulence-driven scenario is often described under the approximation of reduced MHD, in which the compressional waves are discarded. However, it turned out from the reduced-MHD simulation that the heating rate of the solar wind is one order of magnitude smaller than required. Motivated by this background, we have performed a three-dimensional, compressional MHD simulation of the fast solar wind with a view to studying the potential role of compressional waves. The Alfven waves are found to efficiently interact with the (compressional) slow-mode waves in the wind acceleration region, leading to the enhanced plasma heating and successful reproduction of the fast solar wind. We have also found that the interaction is probably driven by the parametric decay instability. Our conclusion is that the solar wind turbulence is driven by a combination of parametric decay instability and conventional Alfven wave turbulence.

KEYWORDS solar wind, turbulence, Alfven wave

Division E

#2723

High-Altitude Instrumentation for Infrared Observations of the Solar Corona

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High-altitude infrared remote sensing is a promising method for measuring coronal magnetic fields and characterizing the surrounding plasma environment. In this talk, I describe recent insights provided by a new CfA airborne spectrometer and outline our upcoming plans for airborne and balloon-borne spectrometers and magnetometers.

Our instrumentation program began with the development of an Airborne InfraRed Spectrometer (AIR-Spec) to measure infrared coronal emission lines during total solar eclipses. AIR-Spec made its commissioning observation from the NSF's Gulfstream V research jet during the 2017 eclipse, when it measured all five of its target lines. These magnetically sensitive emission lines are promising candidates for future observations of the coronal magnetic field, and their characterization was an important first step toward developing the next generation of coronal magnetometers. The second AIR-Spec research flight took place during the 2019 eclipse across the southern Pacific. Higher sensitivity and reduced jitter enabled more precise measurements of plasma density, temperature, and line-of-sight velocity further from the solar limb. In 2020 and 2021, we developed and flight-tested the Airborne Stabilized Platform for InfraRed Experiments (ASPIRE), a new large-aperture solar tracking platform for the Gulfstream V. During the 2024 North American eclipse, ASPIRE will feed the Airborne Coronal Emission Surveyor (ACES), a new imaging Fourier transform spectrometer that will survey the 1 – 4 micron wavelength band to look for new lines for plasma and magnetic field diagnostics. In parallel with ACES, we are developing a balloon-borne coronagraph and spectropolarimeter that will observe the Sun continuously for at least one solar cycle from above Antarctica. The COROnal Spectropolarimeter for Airborne Infrared Research (CORSAIR) will measure the magnetic and thermodynamic evolution of the corona and is a pathfinder for future space missions.

KEYWORDS solar corona, infrared, magnetic field, spectroscopy, instrumentation

Division E

#354

Large-scale structures in the heliosphere and their Space Weather impact

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Most dynamic phenomena on the Sun are observed as coronal mass ejections (CMEs) and flares. CMEs present massive clouds of magnetized plasma having speeds up to a few thousand km/s, that may propagate over the Sun-Earth distance within less than a day and may cause strong geomagnetic disturbances at Earth (Space Weather). CMEs are embedded in the ambient solar wind flow which is structured itself due to interaction slow and fast wind streams. The sources of the fast wind streams are clearly different from the slow ones. The so-called stream interaction regions (SIRs) may cause geomagnetic storms too, and may periodically return. Especially the interaction between CMEs and CMEs and SIRs is of interest, as Space Weather effects may intensify. Therefore, a better understanding of the physical processes involved in the interaction between solar wind flow and CMEs enable us to improve models for more reliable forecasts. The talk will cover CME-flare phenomena and the interplanetary propagation behavior of CMEs related to the background solar wind, and how to tackle Space Weather forecasting with models.

KEYWORDS Sun, Heliosphere, CMEs, Solar Wind, Space Weather

Division E

#964

Space weather across the time scales: Minutes to millennia

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Space weather has long been known to approximately follow the solar cycle, with geomagnetic storms occurring more frequently at solar maximum than solar minimum. There is much debate, however, about whether the most hazardous events follow the same pattern. Extreme events – by definition – occur infrequently, and thus establishing their occurrence behaviour is difficult even with very long space-weather records. Direct spacecraft observations of the solar wind provide a near-continuous 60-year record of the near-Earth space environment. Ground-based magnetometer measurements can be used to infer space weather back around 150 years. And the sunspot record can provide information about solar activity for around 400 years. Reconstructing the spaceweather and climate on time scales longer than a few centuries requires the use of even more indirect proxies such as galactic cosmic rays (GCRs), near relativistic charged particles which originate outside of the solar system, at astrophysical objects such as supernovae. As charged particles are deflected by magnetic fields, the Sun's magnetic field partially shields Earth from GCRs. When GCRs do enter the Earth's atmosphere, they collide with air molecules and create a shower of exotic decay products. These include isotopes which do not naturally occur, such as Carbon-14 and Beryllium-10. Such "cosmogenic" isotopes are removed from the atmosphere and deposited in biomass and ice sheets, respectively, providing natural records of GCR intensity, and hence the Sun's magnetic field, over the last 9,400 years or so. This talk will aim to summarise our knowledge of space weather from these diverse sources and how predictability can be exploited across the time scales.

KEYWORDS space weather, solar activity, solar cycle, solar wind

Division E

#655

Do we understand the physics of extreme solar events?

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Sun sporadically produces eruptive events such as solar flares and coronal mass ejections which can lead to very intense fluxes of solar energetic particles (SEPs) observed near Earth and pose serious hazards for our modern technological society. Presently, the strongest directly observed solar flare was of ~4·1032 erg energy (04-Nov-2003) and SEP event of ~5000 % enhancement (23-Feb-1956). Can even stronger events appear? How much stronger and how often? What could be the "worst-case scenario"? Answers to these questions can be only obtained by indirect methods, viz. cosmogenic isotopes (14C, 10Be, 36Cl) measured in terrestrial archives and lunar rocks, as well as an extensive statistic of the superflares on sun-like stars. The seemingly inconsistent results from the two methods will be presented and physical processes discussed that may help resolve the discrepancy. It is particularly interesting whether extreme events on the Sun and stars are “black swans” (similar to normal solar flares but just greater in scale) or “dragon kings” (presently unknown type of phenomenon requiring new physics to be developed). Although the definite answer is not known yet, existing arguments will be summarized and discussed.

KEYWORDS solar flares, extreme events, cosmogenic isotopes

Division E

#396

Recent developments in space weather research with high fidelity low-frequency spectro-polarimetric imaging using SKA-low precursor

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Low-frequency radio observations have been expected to serve as a powerful tool for Space Weather observations for decades. Radio observations are sensitive to a wide range of Space Weather-related observations ranging from emissions from coronal mass ejections (CMEs) to the solar wind. The ground-based radio observatories allow the gathering of high sensitivity data at high time and spectral resolution, which remains a challenge for most space-based observatories. While radio techniques like Interplanetary Scintillation (IPS) are well established in Space Weather research, radio imaging studies have remained technically challenging. This is now changing with the confluence of data from instruments, like the Murchison Widefield Array (MWA), a SKA precursor, and the robust unsupervised analysis pipelines developed by our group. Recently, we have implemented a precise polarization calibration pipeline, which delivers full Stokes radio images with unprecedented fidelity and dynamic range. This will serve as a powerful tool for heliospheric and Space Weather research and here we showcase some capabilities of this pipeline. An example includes measuring plasma parameters and magnetic fields of CMEs out to 8.5 solar radii using gyrosynchrotron modeling of full Stokes spectra. We will share the current status of the objective to measure the heliospheric Faraday rotation towards numerous background linearly polarised radio sources with the Sun in the field of view. We envision that in coming years, with the availability of instruments like the SKA and others, such spectro-polarimetric radio observations, combined with simultaneous IPS measurements would routinely complement the current tools available for Space Weather monitoring. With Aditya-L1 on the horizon, this is a very timely development and combined with data from existing space-borne assets like SDO and SOHO, it will mark the start of a new era in Space Weather modeling and prediction.

KEYWORDS Sun and Heliosphere, Heliospheric magnetic field, Radio Observation, Polarization, Coronal Mass Ejections, Radio Bursts, Faraday Rotation

Division E

#593

Heating of ions at the Supercritical and Subcritical Quasi-perpendicular Earth's Bow Shocks

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In the shock theory, the solar wind ions are fully thermalized across the bow shock and the ion thermalization should result in a Maxwellian distribution. It has been suggested that the reflected, gyrating ions play a substantial role on ion heating across the quasi-perpendicular bow shock and contributed to a temperature anisotropy of the ions at the boundary of a quasi-perpendicular bow shock. In our previous report, we show that the directly transmitted solar wind ions and the reflected, gyrating ions experience different heating processes as they transport across the Earth's supercritical quasi-perpendicular bow shock. The reflected, gyrating ions are strongly heated as expected in a shock theory while the directly transmitted solar wind ions are only slightly heated by compression of the magnetic field. These two populations do not thermalize into a single population even as they travel deeply into the magnetosheath. In this presentation, we show a quasi-perpendicular shock event on 27 January 2003 observed by Cluster spacecraft, which of observation location is a dusk side of Earth's magnetosphere and distance from the Earth's is ~15 Re. Upstream solar wind conditions derived from Cluster HIA moment data are the plasma beta of 0.53 and the Alfven Mach number of 4.4 when the shock crossing is observed. The shock changes from a supercritical to subcritical following very low ion density and dynamic pressure. At the supercritical shock crossings, the observation shows the same results as our previous report, but at the subcritical shock, the core component remains with large temperature anisotropy while the hot component almost disappears. The velocity space distributions for subcritical period are similar to the distributions in the upstream region. Our results clearly show that the core component is heated adiabatically in supercritical and subcritical quasi-perpendicular bow shocks. Also, the absence of the hot component at the subcritical shock indicates that the dispersed ions in the transition region significantly contribute to the ion heating observed at the supercritical regime.

KEYWORDS solar wind, bow shock, Earth's magnetosheath, ion heating, thermalization

e-Posters

Division E

#3355

CODEX Data Processing

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Coronal Diagnostic Experiment (CODEX) is a diagnostic coronagraph developed by the Korea Astronomy and Space Science Institute and the NASA Goddard Space Flight Center (GSFC) to be deployed in 2023 on the International Space Station (ISS). It is designed to obtain simultaneous measurements of electron density, temperature, and velocity in the 2.5 – 10 solar radius range using multiple filters. The observed data is processed from Level 0 to the higher levels. Level 0 is the data packets or compressed image files replicating what was on board before being packetized. Onboard processing may have been applied. Level 1 is FITS files with uncompressed images with header information from the image header and available ancillary data. Values are in raw counts. Level 2 is FITS files with calibrations applied. Calibration includes corrections on dark, exposure duration, calibration factor, pointing, polarization. Values are in physical units. Level 3 is the result of combining two or more images or derived quantities. Images are integrated in space and time, polarization properties are derived, and then temperature and speed are derived.

KEYWORDS Solar instruments, Solar optical telescopes, Coronagraphic imaging, Calibration, Polarimetry, Solar corona, Solar wind

Division E

#3254

A New Method for Quantitatively Classifying Solar Active Regions

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Classification of solar active regions (ARs) follows a conventional method based on their morphological characteristics. Although it provides a simple way to classify ARs, the method cannot provide quantitative comparison between ARs, thereby limiting the quantitative discussion of ARs. On the other hand, the so-called relative magnetic helicity may be a quantity representing the magnetic field configuration of an AR, and it provides information on the activity of the AR to some extent, although the quantity is derived from the integral operation that removes all characteristics of spatial distributions in the AR. Furthermore, since the relative magnetic helicity depends on not only the field-line twist representing stored free magnetic energy but also total magnetic flux in an AR, taking a large positive or negative value of it does not necessarily indicate that the AR is "really active".

Here we propose a new method for quantitatively classifying ARs, which is based on characteristics of α-distribution. As the spatial distribution of gas density provides information on the gravity of a system, we considered that the α-distribution gives information on the activity of an AR. From the α-distribution we calculated its Laplacian. We applied this method for ARs obtained from nonlinear force-free field reconstructions using photospheric data of flux-emergence simulation and observation. In both cases we found a common negative correlation between the α-distribution and its Laplacian. We show a physical interpretation of this correlation and discuss how our method can be used to quantitatively classify ARs.

KEYWORDS activity, corona, magnetic fields, sunspots

Division E

#2937

The First Large Sunspot of Solar Cycle 25: AR 2786

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In this study, using the data of Istanbul University Observatory, the first observed big sunspot of Solar Cycle 25, AR 2786 are presented.

KEYWORDS Solar Cycle, Sunspot, Sun

Division E

#2817

Determination of 3-D parameters of coronal mass ejections using a deep learning method

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In this study, we present a new method to determine three-dimensional parameters of coronal mass ejections (CMEs) using a deep learning method. For this study, we consider a Convolutional Neural Network (CNN) method which is a popularly used algorithm in image recognition. As a first step, we develop a deep learning model using synthetic CME images. A synthetic CME image is generated by a full ice-cream cone model and a power-law density distribution for given three-dimensional parameters set (radial height, angular width, latitude, longitude). We generate 110,000 synthetic CME images with different three-dimensional parameters: 80,000 for training, 20,000 for validation, and 10,000 for test. As a preliminary results, we obtain root mean square errors between the three-dimensional parameters of the test data set and those of our model: 3 Rs for the radial height, 13.4 for the angular width, 6° for the latitude and 12° for the longitude. We are improving the model by optimizing hyper parameters and modifying input images.

KEYWORDS CME, Deep learning, Sun, Forecast

Division E

#2525

Total Solar Eclipse 2021 at Union Glacier base in Antarctica

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On December 4th, 2021, Antarctica witnessed a Total Solar Eclipse, an awe-inspiring experience for general public and a interesting phenomena to observe scientifically. An expedition with adapted and portable equipment was organized to Union Glacier base, the only settlement on Earth under the path of totality. In this talk, I will present preliminary results of the coronal observations with a variety of camera and lenses, as well as precise atmospheric measurements. The latter are specially important as they provide an unique opportunity to study the atmospheric response of Earth to a sudden decrease of Solar flux under the extreme conditions of the Antarctica continent, a phenomena that happens in Antarctica only every approximately 20 years.

KEYWORDS Eclipse, Antarctica, Atmosphere, Solar Corona

Division E

#313

Quiet-Sun coronal loops: Models and Coronal Heating Implications

Cristina Mandrini[1], Cecilia Mac Cormack[1], Marcelo López Fuentes[1], Diego Lloveras[1], Alberto Vásquez[1]

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The structure of the solar corona is made of magnetic flux tubes or loops. Due to the lack of contrast with their environment, observing and studying coronal loops in the quiet Sun is extremely difficult. We use a differential emission measure tomographic (DEMT) technique to reconstruct, from a series of EUV images covering an entire solar rotation, the average 3D distribution of the thermal properties of the coronal plasma. By combining the DEMT products with extrapolations of the global coronal magnetic field, we reconstruct coronal loops and obtain the energy input required to keep them at the typical million-degree temperatures of the corona. We statistically study a large number of reconstructed loops for Carrington rotation (CR) 2082 obtaining a series of typical average loops of different lengths. We look for relations between the thermal properties and the lengths of the constructed typical loops and find similar results to those found in a previous work. We analyze the typical loop properties by comparing them with the zero-dimensional (0D) hydrodynamic model Enthalpy-Based Thermal Evolution of Loops (EBTEL). We explore two heating scenarios. In the first one, we apply a constant heating rate assuming that typical loops are in quasi-static equilibrium. In the second scenario we heat the plasma in the loops using short impulsive events. We find that the reconstructed typical loops are "overdense" with respect to quasi-static equilibrium solutions. Impulsive heating, on the other hand, reproduces better the observed densities and temperatures for the shorter and approximately semicircular loops. We suggest that to properly assess the physical characteristics of the analyzed loops, it would be necessary to use a more sophisticated model with which to study loop temperature and density profiles and test localized heating at different locations.

KEYWORDS Sun: Corona, Sun: Magnetic field, Sun: Quiet, Sun: Coronal Heating

Division E

#1952

The Heating of a Solar Coronal Loop by Flux Tube Interactions and Small-scale MHD Effects inside an Individual Flux Tube

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Three-dimensional magnetohydrodynamic (MHD) simulations are performed to investigate the energy transport mechanism contributing to the heating of a solar coronal loop. We model a coronal loop from the upper convection zone to the corona with self-consistent thermal convection. A coronal loop consists of multiple flux tubes. Our setup allows us to study the generation of high-frequency MHD waves inside an individual flux tube and the interactions of neighboring flux tubes. Consequently, we have found that energy flux into the corona increases when a magnetic concentration in the photosphere merges with its neighboring one, indicating the merging of neighboring flux tubes. In addition, the energy cascade in the chromosphere enhances the high-frequency components of MHD waves penetrating the corona. We have concluded that these effects in the atmosphere below the corona are essential for coronal heating.

KEYWORDS Sun: magnetic fields, Sun: corona, Sun: chromosphere, Sun: photosphere, Sun: atmosphere, stars: coronae, (magnetohydrodynamics:) MHD

Division E
#1775

Solar flares observed by STIX onboard Solar Orbiter

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After the launch of the Spectrometer Telescope for Imaging X-rays (STIX) onboard Solar Orbiter on 10 February 2020, it is recording solar X-rays uninterruptedly since January 2021 covering the rising phase of solar cycle 25. STIX registers continually X-ray flux in five passbands covering soft and hard parts of the spectrum from 4 up to 80 keV with 4 s cadence. We present a list of all flares registered by the instrument, observed during close approaches to the Sun as well as further parts of the S/C orbit. To the X-ray observed flare light curve standard flare profile as described in the Gryciuk et al. (2017) were fitted. The result is a comprehensive catalogue which contains several thousand flares or flare-like events and is made available for general use.

KEYWORDS flares, X-ray, STIX, Solar Orbiter, catalog

Division E

#1303

On the way to a coronal arch disruption: Dispersion analysis of the Weibel instability in a magneto-active plasma with hot anisotropic electrons

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We show that a coronal arch can be destroyed by the Weibel instability due to an injection of energetic (multi-keV) electrons from a chromospheric plasma. We present an analytical study of the instability in a collisionless bi-Maxwellian plasma with a two-temperature electron velocity distribution in the presence of an external magnetic field. An influence of this field had not been analyzed in detail. However, it is known that it suppresses but does not exclude this instability leading to a filamentation of currents along the external field if the latter is not too strong.

We find a dependence of the Weibel growth rate on the electron anisotropy, temperature and density of plasma as well as on the strength of external magnetic field and the value and orientation of a wave vector of a magnetic-field perturbation. We estimate a power of a quasi-magnetostatic turbulence arising in an upper part of a coronal arch and prove that a saturated small-scale magnetic field can be greater than or of the order of a typical magnetic field of the arch. We argue that a small-scale reconnection of the magnetic-field lines, a partial destruction of the large-scale magnetic field, and, consequently, a coronal mass ejection are possible, if there is a sufficiently high degree of the electron anisotropy.

We consider in detail the most preferable case when the anisotropy axis is oriented along the external magnetic field, while the orientation of the wave vector of unstable modes is across this axis. In this case, the spatio-temporal scales of the Weibel instability are found, the expected structure and strength of the emerging quasi-magnetostatic fields are established, and possible scenarios for the reconnection of magnetic field lines on various scales are proposed. The qualitative analysis of the Weibel instability and a significant restructuring of the magnetic field of the coronal arch are confirmed by modeling the nonlinear process by the particle-in-cell method.

KEYWORDS coronal arch, Weibel instability, magnetic-field reconnection, filamentation, PIC simulation, bi-Maxwellian plasma

Division E

#961

The Time Behaviour of the Calcium Abundance in Flare Plasmas from X-ray Spectra

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The Bent Crystal Spectrometer (BCS) on NASA's Solar Maximum Mission operated between 1980 and 1989 over one of the most active solar cycles in recent history, and the instrument remains the highest-resolution solar X-ray spectrometer to date. Recent revision of BCS instrument characteristics (Sylwester et al. 2021) has enabled the abundance of calcium A(Ca) to be determined from lines-to-X-ray continuum measurements during flare decays with much improved precision. Flare decays were chosen to minimise the risk of significant departures from ionization equilibrium. The determination of A(Ca) is as precise as only 1 to 3% from spectra for which the emitting temperature (from satellite-to-resonance line ratios) is greater than 5MK, enabling the behaviour of any time variations during each of the flare decays to be examined. We found, as might be expected, that for most flare decays in our sample that A(Ca) remains constant (at A(Ca) = 6.8 on a logarithmic scale with A(H) = 12, or about three times photospheric) but that there are variations with time - some showing slightly decreasing, others slightly increasing A(Ca). Definite "segments" during some flare decays can be recognized during which the rate of decay/rise is different. We discuss these results and present possible physical scenarios which may account for the observed abundance changes.

KEYWORDS Sun, corona, flares, abundances, X-rays

Division E

#955

Simultaneous determination of abundances and differential emission measure distributions based on flare X-ray spectra

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We present a multi-wavelength analysis of the flare observed on 7 May 2021 (SOL2021 19:10 UT). This flare was observed by a number of space instruments including STEREO-A/SECCHI, STIX and Solar X-Ray Monitor (XSM) on board Chandrayaan-2. STIX data provided the opportunity for the detailed analysis of hard X-ray emission in different energy bands covering light curves, the hard X-ray images and spectra.

The STEREO-A images have been used to study evolution of flaring loops geometry. The differential emission measure diagnostics of the flaring plasma have been carried out based on XSM X-ray spectra. Using the differential evolution (DE) method we have determined the model of emitting source: temperature, emission measure and elemental abundances simultaneously. The DE approach was used to study the evolution of source plasma model for several times during the event progress. The results obtained will be shown and discussed.

KEYWORDS Sun, Flare, Abundances, Differential Emission measure, Differential Evolution

Astronomy for All
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Division E

#831

Relativistic acceleration of electrons in solar flares

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The acceleration of electrons in solar flares by electron gyroresonance with whistler mode waves has previously been modeled as a stochastic process by means of a Fokker-Planck diffusion equation. Here we present a new mechanism for electron acceleration in solar flares called ultra-relativistic acceleration (URA). This mechanism applies in general to a magnetic mirror geometry and has been successfully applied to planetary radiation belts. URA comprises electron energization due to a special form of nonlinear phase trapping by a coherent whistler-mode wave. Electrons must possess a critical minimum kinetic energy which depends on the wave frequency and the electron gyrofrequency at the center of the mirror (or equator of an assumed dipole-like magnetic field). Electrons that encounter relativistic turning acceleration (RTA) followed by multiple URA interactions can undergo significant energy increase. Under ideal conditions, at Jupiter several-hundred-keV electrons can be energized by tens of MeV in a few tens of seconds. URA can hence play a prominent role in generating electrons with energies of tens-of-MeV (and beyond) observed in the Jovian magnetosphere. Likewise,we postulate that multi-MeV electrons can be generated by URA in solar flares. Necessary conditions for the URA and RTA mechanisms include an abundant supply of seed electrons and multiple whistler-mode wave packets of sufficient duration.

KEYWORDS solar flare, electron acceleration, nonlinear phase trapping, whistler-mode waves

Division E

#726

LINKS BETWEEN PROMINENCE/FILAMENT MAGNETIC FIELD AND PLASMA: WHAT CAN 3D WPFS MODELS TEACH US?

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A strong imbalance exists between the numerous efforts in detailed modelling of prominence magnetic field and its understanding from observations. That is due to the complex nature of the direct (and indirect) observations of solar magnetic fields which require high-precision spectro-polarimetric measurements and realistic assumptions about the plasma structure to infer the field configuration from its effect on the polarized light emergent from the observed structures. The indirect observations rely on the perceived location, shape and dynamics of the prominence or filament plasma, often using moving small-scale plasma structures as tracers guided by the field lines. Both methods thus rely on the presence of observable plasma in the magnetic field configuration, and on the radiation which carries the information about the in-situ conditions to the observer. No prominence/filament magnetic field measurements are made without these two additional components, which are sometimes an afterthought in the magnetic field models.

We have developed 3D Whole-Prominence Fine Structure (WPFS) models to illuminate the links between the prominence magnetic field, its plasma distributed among numerous fine structures and the radiation which carries the information about the prominence physical conditions to the observer. What can we learn from these 3D models? For example, we can see that a small change of the magnetic field configuration can have a large effect on the perceived structure of prominences and filaments visible in the H-alpha line. Consequently, this means that significant changes observed in prominences or filaments do not need to suggest that equally large changes in the underlying magnetic field configuration had to occur. In another example, we see that seemingly incomparable differences in the morphological look of prominences (long horizontal fine structures versus small blobs of plasma arranged into more-less vertical features) may not need to imply the existence of radically different magnetic field configurations. Rather, they might simply be manifestations of projection effects that can differ greatly depending on the viewing angle under which we observe the naturally three-dimensional prominences/filaments.

KEYWORDS Solar prominences, Magnetic field modelling

Division E

#318

Investigating solar wind plasma variability during major geomagnetic storms of solar cycle 23-24

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We study the variation on plasma beta, Alfven Mach number, and magnetosonic Mach number during major geomagnetic storms of solar cycles 23 and 24. In our analyses, we also include the flow pressure, proton density, temperature, and velocity of the solar wind, the Interplanetary Magnetic Field (IMF) Bz, and SYM-H magnetic indices. The effects of both coronal mass ejections (CME) and co-rotating interaction regions (CIR) to these variables are inter-compared looking for coupling mechanisms. Our results show large-amplitude waves occur preferentially soon following the overshoot of shock with rising Alfven Mach number and plasma beta, and without changes in magnetosonic Mach number only in CME driven storms. CIR-driven storms lack such features. The study of solar wind plasma variability and coupling with magnetic forcing during major geomagnetic storms is a key study to better understand and predict space weather effects on human activities.

KEYWORDS Geomagnetic Storms, Solar Wind, Plasma Beta, Alfven Mach Number

e-Talks

Division E

#3415

Towards a full reconstruction of the sunspot number: challenges and impacts

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We will quickly present the international effort that led to the first-ever revision of the Sunspot and Group Numbers (let us call them "the Sunspot Series"). The well-known Sunspot Number, for example, had never been revised extensively since its creation by Rudolf Wolf in 1849. We will review the different methods currently applied and envisioned for future versions of the two series (ISSI review paper, https://www.issibern.ch/teams/sunspotnoser/).

Since this first revision in 2015 (Solar Physics Topical Issue, 2016), the Sunspot Series have become living datasets that require constant monitoring since more source data are being recovered regularly (Arlt & Vaquero, 2020) and different stitching techniques are tested, the most recent one being a technique that, just as the ADF (Usoskin et al., 2016) does not require any temporal overlap between datasets, and uses tied ranking.

After this "small" review of previous efforts, we will focus more specifically on the reconstruction of the International Sunspot Number from raw sunspot data. With the team from ISSI, we are currently driving a large effort to gather raw data from all around the world. At the Royal Observatory of Belgium, within the WDC-SILSO (https://wwwbis.sidc.be/silso/) where the original Mittheilungen have been digitized (2017-2019) we also have 2 PhD students working on stitching historical and modern sunspot numbers and evaluating the quality of the reconstructed series through advanced statistical techniques. We will present the current status of this reconstruction and its challenges.

KEYWORDS sunspot number, sun, reconstruction, solar, statistics, group number

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Division E

#3211

Coronal arch disruption and dispersion analysis of the Weibel instability in a magneto-active plasma with an anisotropic distribution of hot electrons

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We show that a coronal arch can be destroyed by the Weibel instability due to an injection of energetic (multi-keV) electrons from a chromospheric plasma. We present an analytical theory of the instability in a collisionless bi-Maxwellian plasma in the presence of an external magnetic field. The latter suppresses but does not exclude the Weibel instability leading to a filamentation of currents along the external field if the latter is not too strong.

We find a dependence of the Weibel growth rate on the electron anisotropy, temperature and density of plasma as well as on the strength of the external magnetic field and the value and orientation of a wave vector of a magnetic-field perturbation. We estimate an intensity of a quasi-magnetostatic turbulence arising in an upper part of a coronal arch and prove that a saturated small-scale magnetic field can be greater than or of the order of a typical magnetic field of the arch. We argue that a small-scale reconnection of the magnetic-field lines, a partial destruction of the large-scale magnetic field, and, consequently, a coronal mass ejection are possible if there is a sufficiently high degree of the electron anisotropy.

We consider in detail the most preferable case when the anisotropy axis is oriented along the external magnetic field, while the orientation of the wave vector of unstable modes is across this axis. In this case, the spatio-temporal scales of the Weibel instability are found, the expected structure and strength of the emerging quasi-magnetostatic field are established, and possible scenarios for the reconnection of magnetic field lines on various scales are outlined. The qualitative analysis of the Weibel instability and a significant restructuring of the magnetic field of the coronal arch are confirmed by modeling the nonlinear process via the particle-in-cell method.

Thus, we propose a novel mechanism and formulate the basis of the theory of a solar flare associated with an individual coronal arch.

KEYWORDS Coronal arch, Weibel instability, Solar flare, Turbulence, Hot electron injection, Coronal mass ejection

Division E

#2392

Solar neutrino fluxes show the signature of planet formation processes

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Solar evolutionary models are thus far unable to reproduce spectroscopic, helioseismic, and neutrino constraints consistently, resulting in the so-called solar modeling problem. In parallel, planet formation models predict that the evolving composition of the protosolar disk, and thus, of the accreted gas by the proto-Sun must have been variable. In this talk, we show that solar evolutionary models including a realistic planet formation scenario lead to an increased core metallicity of up to 5%, implying that accurate neutrino flux measurements are sensitive to the initial stages of the formation of the Solar System. We demonstrate that in addition to macroscopic transport and increased opacities at the base of the convective envelope, the formation history of the Solar System constitutes a key element to resolve the current crisis of solar models.

KEYWORDS Sun: abundances, Sun: interior, stars: protostars, stars: pre-main sequence, accretion, accretion disks, Protoplanetary disks, Planet formation

Astronomy for All
Busan 2022

Division E

#2245

Predictions and Forecasts Using Worldwide Interplanetary Scintillation Stations (WIPSS) network and STEREO A HI Data

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The University of California, San Diego (UCSD) time-dependent three-dimensional (3-D) reconstruction technique provides volumetric maps of density, velocity, and solar surface extrapolated magnetic fields by iteratively fitting a kinematic 3-D model to interplanetary scintillation (IPS) observations. While we currently use data from the Institute for Space-Earth Environmental Research (ISEE), Japan, we have also integrated this system adding data from Worldwide IPS Stations (WIPSS) network groups to increase both spatial and temporal coverage when these data are available. In addition we have recently adapted the UCSD Solar Mass Ejection Imager (SMEI) iterative tomography analyses for use with STEREO A Heliospheric Imagers (HIs) to provide 3-D reconstructed plasma densities of the inner heliosphere in the region viewed by these instruments. The UCSD 3-D iterative reconstruction technique is unique in its ability to yield a low-resolution seamless extension of density and velocity parameters measured in situ, going outward into the surrounding interplanetary medium at the resolution of the volumetric data. We here present analyses using archival data sets from ISEE, LOFAR, and the STEREO A HIs. These analyses provide plasma parameters values at the locations of all inner planets from Mercury to Mars, and at the spacecraft PSP, BepiColombo, and Solar Orbiter in the 3-D reconstructed volumes. This allows a test and a fit to in-situ plasma measurements obtained at these locations both as a prediction of the parameters from archival data sets, and when run as in near real time, provide a testable forecast before the plasma structures arrive at any one given location.

KEYWORDS space weather forecasting, solar wind, helisopheric remote sensing, interplanetary scintillation, Thomson scattering, CMEs, SIRs

Division E

#2055

Exploring the Origin of Solar Eruptive Events Using Magnetofrictional Simulations

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Coronal mass ejections (CMEs) are the most energetic events originating from the Sun. They can cause significant and sudden disruption to the magnetic and particulate environment of the heliosphere. Thus, in the current era of space-based technologies, an early warning that a CME has left the Sun is crucial. Our magnetofrictional simulations that capture the global corona's continuous and dynamical evolution over many months demonstrate that the non-potential evolution of the corona leads to the accumulation of magnetic free energy and helicity, which is periodically shed in eruptive events. We find that these events fall into two distinct classes: One set of events is caused by eruption and ejection of low-lying coronal flux ropes, and they could explain the origin of filament-erupting CMEs. The other set of events is not driven by the destabilisation of low-lying structures but rather by eruption of overlying sheared arcades. These are associated with streamer blowouts or stealth CMEs which are sources of problematic geomagnetic storms. Further investigation on the second class of events predicts the occurrence of repeated eruptions without clear low-coronal signatures from such arcades, provided that the high, overlying magnetic field lines are sufficiently sheared by differential rotation. Thus, our study suggests that magnetofrictional models can, in principle, provide early indication - pre-onset of CMEs, irrespective of whether they originate from the eruption of a low-coronal flux rope.

KEYWORDS Solar Corona, Modelling, Coronal Mass Ejections, Predictions

DIVISION F

Planetary Systems and Astrobiology

Invited & Contributed Talks

Division F

#473

Exploration of habitable worlds in the outer solar system: the icy moons

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Besides Mars, currently under extensive exploration, the large satellites of the gas giants Jupiter and Saturn, at orbits beyond the snow-line and the traditional "habitability zone", have been revealed as extremely astrobiologically interesting bodies by missions like Galileo, Cassini-Huygens and Juno, presenting promising conditions for habitability and the development and/or maintenance of life. Jupiter's Europa and Ganymede show indications of harboring liquid water oceans under their icy crusts, which, in the case of Europa, may be in direct contact with a silicate mantle floor and kept warm through time by tidally generated heat. Around Saturn, Titan and Enceladus, were found to possess organic chemistries with seasonal variations, unique geological features and internal liquid water oceans [1]. The icy satellites provide a conceptual basis within which new theories for understanding habitability can be constructed.

In view of many questions remaining unanswered after the current and past missions (e.g; for Titan, [2]), these bodies will be further investigated in the future by missions to the giant planets systems. Future exploration towards the Galilean satellites include missions such as ESA's JUpiter Icy moons Explorer (JUICE, [3]) (whose main target is Ganymede and will be launched in 2023 for arrival in the jovian system in 2031) and NASA's Europa Clipper mission. For a return to Titan, NASA has recently selected the Dragonfly mission [4] and other concepts are being studied. I will focus on the new scientific insights that will be offered by JUICE and Dragonfly.

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KEYWORDS icy moons, Titan, Europa, Ganymede, Enceladus

Division F

#974

Exploring the free-floating planet population with gravitational microlensing

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Thousands of extrasolar planets have been discovered up to date. Although many of the known exoplanets do not resemble those in our Solar System, they have one thing in common - they all orbit a star. However, theories of planet formation and evolution predict the existence of free-floating planets, gravitationally unattached to any star. They may form as a result of dynamical processes in young planetary systems or during late stages of host star evolution.

Gravitational microlensing is uniquely suited for finding free-floating planets. I will present the current constraints on the frequency and properties of rogue planets in the Milky Way based on long-term observations of microlensing events in the Galactic bulge by the OGLE sky survey. I will also present several of the most promising candidate free-floating planets discovered to date. Finally, I will briefly discuss the future prospects for determining the frequency and mass function of rogue planets by the planned microlensing experiments.

KEYWORDS free-floating planets

Division F

#383

Rings and Spirals in Protoplanetary Disks: The ALMA View of Planet Formation

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The ubiquity and diversity of planets tell us that they can emerge under an astonishing range of conditions. By enabling us to map the distributions of dust grains and molecules in protoplanetary disks at an unprecedented level of detail, the Atacama Large Millimeter/Submillimeter Array (ALMA) has transformed our understanding of planet formation. In the Disk Substructures at High Angular Resolution Project (DSHARP), we undertook the first high angular resolution disk survey at millimeter wavelengths. Although protoplanets are difficult to detect directly, the widespread presence of dust gaps and rings in disks suggests that giant planet formation occurs readily on Myr-timescales at surprisingly wide separations. Meanwhile, deep observations of molecular emission have revealed complex large-scale structures associated with protoplanetary disks, indicating that environmental interactions play a more important role in disk evolution and planet formation than previously assumed. ALMA has also revealed strong chemical heterogeneity within and among disks, laying the observational groundwork for investigating the link between the compositions of planets and their formation location. Together, these new data show that the natal environments of planets are far more dynamic and varied than earlier observations have indicated.

KEYWORDS Protoplanetary Disks, Planet Formation, Radio Interferometry

Division F

#737

Comparative meteoroid fluxes on planetary atmospheres

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The inner solar system is populated by Interplanetary Dust Particles (IDPs) released from cometary trails and collisions between asteroids. Planetary bodies and satellites therefore encounter a cloud of IDPs along their orbits, giving rise to a permanent bombardment on their respective atmospheres or surfaces. Constraining the magnitude of the mass influx of IDPs onto a solar system body is crucial for understanding the effects in their atmospheres and on their surfaces. Astronomical dust models are therefore required to characterize the production, transport, and temporal and spatial evolution of dust grains from their sources – Jupiter Family Comets, main belt Asteroids, Halley-Type Comets, and Oort-Cloud Comets – to sinks – sublimation, impact on a solar system body or departure from the solar system.

Most IDPs are stony chondrites consisting of a Mg-rich silicate backbone with major Na-plagioclase and metallic Fe or iron sulfide (FeS) inclusions. In the case of planetary bodies with atmospheres, collisions with air molecules lead to the thermal ablation of IDPs above their melting temperature and, therefore, their constituent elements evaporate and produce layers of free neutral and ionized atoms. Mg, Fe, Si, and Na are the major metallic species in the Earth's upper atmosphere, while K and Ca are present at least one order of magnitude lower in concentration. Metallic layers in the Earth's atmosphere have been widely studied for decades using ground-based lidar and space-based optical spectroscopy. These observations show that Mg+ and Fe+ are the metallic constituents of the lower E region.

Here we review the advances in interplanetary dust modelling and meteoric ablation in the upper atmospheres of Venus, Earth, and Mars. For comparison, meteoric ablation occurs between 130 and 60 km at Earth, 120 and 40 km at Mars, and 130 and 95 km at Venus. The injection rate profiles for Earth peak ~10 km higher than for Mars, and ~20 km lower than for Venus. Moreover, the accretion rate of unmelted particles at the Martian surface is around 60% of the overall mass influx, providing a constant fluence of intact carbon.

KEYWORDS Zodiacal Cloud, Short-Period Comets, Long-Period Comets, Asteroid belt, Meteoroids, Meteors, Planetary atmospheres

Division F
#1518

Gaussian processes for high-resolution spectroscopy

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High-resolution spectroscopic observations from the ground have proved effective for exoplanet atmospheric detection in the last decade. Using cross-correlation methods, scientists have detected numerous atmospheric chemical species, and more recently log-likelihood mappings have even enabled gas abundance measurements. These techniques are heavily dependent on the careful distinction of the planet spectrum from the myriad of noise sources, the dominant contributions being from the host star and the Earth's atmosphere. Known as 'detrending', these noise sources must be modelled and removed from the observations prior to attempting to detect the planet. The planet spectrum is usually unseen, buried in the noise. We have established a Gaussian process (GP) regression framework, which models the component spectra sequentially. Though GPs alone do not yet match the sensitivity of cross-correlation methods, obtaining a planet spectrum estimate affords a number of benefits. This allows us to visualise the impact of the detrending process on the planet's spectrum - we show that standard detrending methods degrade the planet spectral lines. It is then important to consider these ahead of any atmospheric retrievals.

KEYWORDS exoplanet, atmosphere, high-resolution, spectroscopy, transmission, emission

Division F

#1422

Detectability of magnetic star-planet interactions in compact exosystems

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Close-in planets are thought to generally orbit in a sub-alfvénic stellar wind. The perturbations they excite in the stellar corona are able to travel upwind down to the stellar surface, and potentially induce observable phenomena. The effective connection between the planet and its host takes the form of two Alfvén wings. The stellar global magnetic field is at the heart of star-planet magnetic interaction: its strength sets the magnetic energy available for the interaction, its shape determines the connection path between the star and the planet, and its temporal modulation (e.g. magnetic cycles) is at the source of an on/off behavior of the magnetic interaction.

I will briefly give an overview of our understanding of star-planet magnetic interactions and propose scaling laws for their amplitude. I will then present specific studies of the 3D star-planet magnetic interactions, in the Kepler-78 system and in HD 189733. I will show how stellar rotation, planetary orbit, and stellar magnetic topology come all in play to modulate the signal from star-planet magnetic interactions. By analysing such signal based on 3D numerical simulations, I will show that we can explain the difficulty to detect them with existing observational campaigns of HD 189733 (e.g. Cauley et al. 2018). Our results warrant dense spectroscopic observational campaigns, coupled to spectro-polarimetric campaigns to firmly detect star-planet magnetic interactions. Such firm detections would open up the possibilities to characterise the magnetic field of distant exoplanets on short orbit.

KEYWORDS star-planet interactions, planetary magnetic field

Division F

#400

New Near-Earth Objects in the Taurid complex

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The Taurid meteoroid stream, comet 2P/Encke being the parent of the stream and more than 40 near-Earth's asteroids which are in fact extinct fragments of the parent comet have form the Taurid comet-asteroid-meteoroid complex. The Taurid stream produces the meteor showers and sub-showers observable on the Earth annually during October-November and May-June. We carried out a new search for asteroids belonging to the Taurid complex. On the base of calculation of orbital evolution of a sample of NEAs discovered in 2004-2015 and determination of theoretical features of related showers a search for observable active showers close to theoretically predicted ones was performed. As a result, predicted showers of 16 NEAs were identified with the showers produced by the Taurid meteoroid stream. Revealed association points to their common cometary origin. New near-Earth's objects alongside with already established ones are moving within the Taurid stream and are very likely extinct fragments of comet 2P/Encke – parent of the Taurid complex or remnants of a larger comet-progenitor that was disintegrated 20-30 thousand years ago.

KEYWORDS comet, asteroid, extinct comet, meteoroid stream, meteor shower, orbit, evolution

Division F

#2028

Geophysical Evolution During Rocky Planet Formation

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In the last few decades astronomical observations have revealed that planetary objects are plentiful in the galactic neighbourhood and truly diverse in nature. However, exoplanet measurements are so far limited to assessing only the most basic parameters, such as radius, mass, and bulk density of a planet, from which detailed characterisation of smaller, Earth- to super-Earth-sized planets remain challenging. In order to gain a more comprehensive understanding of these worlds, contextual information on the delivery of major volatile elements and constraints on physical and chemical mechanisms that shape their structure and evolution are needed. I will discuss how the inhomogeneous enrichment of forming planetary systems with short-lived radionuclides like Al-26 in typical star-forming environments influences the interior evolution and volatile loss of planetesimals that accrete to form terrestrial-like planets. The resulting internal geophysical evolution of growing planetesimals sub-divides rocky planets into distinct populations: enriched systems with Solar-like or higher levels tend to form volatile-depleted planets, while barely-enriched systems dominantly form ocean worlds. In the Solar System, geophysically-evolving bulk composition driven by short-lived radionuclide heating offers an explanation for key trends in the distribution of core formation ages and aqueous alteration in planetary bodies and the volatile and isotope fractionation between the inner and outer Solar System. The link between planetary bulk composition and radioactive heat sources that originate from massive stars suggests a direct correlation between the star-forming birth environment of exoplanetary systems and the climatic and geodynamic evolution of rocky planets that form in them. Observations of mass-radius trends on a population level and detailed characterisation of select super-Earths in the upcoming years will offer opportunities to provide novel insights into the volatile history and evolutionary paths of rocky worlds.

KEYWORDS exoplanets, planet formation, star formation

Exoplanets Atmospheres and Habitability

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The discovery of thousands of transiting exoplanets in the last decade, and the ones that will be detected with TESS and the upcoming generation of high resolution telescopes, makes the characterization of exoplanets atmospheres one of the most interesting fields of the next decade. By analyzing the atmosphere of these planets, we can infer their composition and obtain information about their formation and evolution. Here we characterized the atmospheres of exoplanets in the visible using the instrument Space Telescope Imaging Spectrograph (STIS) on board of the Hubble Space Telescope (HST). In the blue wavelengths one can constrain the presence of Rayleigh scattering due to clouds and hazes that play a critical role in the atmospheric temperature structure and dynamics of the planet. Up to date, most of the planets observed with HST are Hot-Jupiters that still hold a primary atmosphere. Unlike the giant planets, there are few HST observations of small close-in planets in the transition region between super-Earths and sub-Neptunes, however they are the representative population of planets detected with transit and radial velocity surveys. These small planets could possibly have a secondary atmosphere. They should attract attention in the next years and thus as second goal we investigate the evolution of the atmosphere of small close-in planets by looking into the relationships between their radius, insolation, and density, and by tracking the evolution of their envelope due to photoevaporation. Although the presence of a secondary atmosphere can be one of the key factors for the habitability of terrestrial planets, other factors can have an impact and need to be taken into account, such as the activity of the host star. Therefore, here we determine the habitability of terrestrial planets using a primitive or a present-day Earth-like atmospheres under the environment of a flaring star. In addition, we also analyse if an ocean in these planets would help to protect life from the harmful stellar UV radiation.

KEYWORDS Exoplanets, Exoplanets Atmospheres, Hubble, UV, flares, terrestrials

Division F

#2077

Analysis of the public HARPS/ESO spectroscopic archive: Jupiter-like planets around HD 103891 and HD 105779

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We use the recently published database (Trifonov et al. 2020) of radial velocities (RVs) that were derived from fifteen years of HARPS/ESO observations to search for planet candidates. For targets with sufficient RV data, we apply an automated algorithm to identify significant periodic signals and fit a Keplerian model for orbital estimates. We also search the auxiliary data of stellar-activity indices and compare our findings with existing literature, to detect periodic RV signals that have no counterpart in the activity timeseries. The most convincing signals are then manually inspected to designate additional false planet detection, focusing the search on long-period (P > 1 000 d) massive candidates around FGK dwarf stars. We identify two Jupiter analogs, in orbit around the slightly evolved F8V star HD 103891 and the Solar-like star HD 105779. We use nested sampling to derive their orbital parameters, and find their orbital periods to be 1919 +/- 16 d and 2412 +/- 54 d, while their minimum masses are 1.44 +/- 0.02 M Jup and 0.64 +/- 0.06 M Jup, respectively. While the orbit of HD 103891 b is slightly eccentric (e = 0.31 +/- 0.03), that of HD 105779 b is likely circular (e < 0.16). With minimum astrometric signatures of 59 and 42 μas, HD 103891 b and HD 105779 b join the growing sample of planets whose exact masses may soon be derived with Gaia astrometry. This finding also highlights the importance of long-term RV surveys to study planetary occurrence beyond the snow line of Solar-like stars.

KEYWORDS Techniques: radial velocities, Astronomical data bases, planetary systems

Division F

#1596

Chemical complexity from star-forming regions to comets

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It has been speculated that chemically complex molecules could have been delivered to Earth during the Late Heavy Bombardment for further synthesis of biotic compounds on the planet. In my talk, I will demonstrate the interstellar origins of cometary molecules. I will suggest that the large complex organic reservoirs in comets make them strong candidates for sowing the initial seeds of life on the early Earth. The earliest stage of star formation, the prestellar core, is the birth place of complex organic molecules under interstellar physical conditions. Upon gravitational collapse, a young protostar with a protoplanetary disk is formed. The concurrent heating and UV irradiation boost the production of complex organics. It is thought that the largest reservoir of complex organics is in interstellar ices. Desorption in the warm inner regions around protostars allows us to readily observe these species in the gas. In the outer parts of a protoplanetary disk, solid complex organics become integrated into cometesimals. I will highlight recent observational investigations of complex organics from cores to protostars, including studies of methanol isotopologs in the prestellar core L1544 (Kulterer et al. in prep.) and the comprehensive chemical inventory of the low-mass star-forming region IRAS 16293-2422 (e.g., Jorgensen et al. 2018; Drozdovskaya et al. 2018, 2022). I will bring forward the idea that comets of our Solar System reflect to a degree the complex organic composition of the innate core that birthed our Sun (Drozdovskaya et al. 2019, 2021).

KEYWORDS astrochemistry, comets, ALMA, Rosetta, complex organic molecules, life, star formation

Division F

#530

Exoplanet atmospheric escape: theory and observations

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The long-term evolution of a planetary atmosphere is predominantly shaped by escape, a process leading atmospheric gas to leave the planet's gravitational well and disperse into space. Escape is a fundamental process affecting planetary atmospheric structure, composition, and evolution. For example, within the solar system, escape is known to have shaped the early atmospheres of Venus, Earth, and Mars. The powerful atmospheric escape that affected these planets in the past no longer takes place in the solar system. However, it can be observed and studied on short-period exoplanets. I will briefly review the theory of exoplanet atmospheric escape, to then focus mostly on the main observational results providing information that improves our understanding of this fundamental process.

KEYWORDS exoplanets, atmospheric escape

Division F

#1052

Enrichment of the primordial Solar System by stellar organics

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Complex organics are now commonly found in comets, asteroids, planetary satellites, and interplanetary dust particles. The common interpretation of the origin of these organics is that they were produced in situ within the Solar System. In this paper, we discuss the possibility of enrichment of the early Solar System by stellar ejecta. Planetary nebulae are now known to produce large quantities of nanoparticles with mixed aromatic-aliphatic structures (MAON). The spectral similarities and possible links between stellar and Solar System organics will be discussed.

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KEYWORDS organics, solar system, chemical enrichment

Division F

#2226

What We Have Learned from Samples Returned from C-type Near-Earth Asteroid (162173) Ryugu

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The first sample from a carbonaceous asteroid was delivered to the Earth from near-Earth asteroid (162173) Ryugu in December 2020. The returned sample, collected at two different surface locations, was ~ 5 grams in total, and currently the largest among samples returned from beyond the Earth-Moon system [1]. The JAXA's Hayabusa2 spacecraft explored Ryugu from June 2018 to November 2019, including two successful landing operations for sample collection. The sample from carbonaceous asteroids are expected to record physical and chemical processes in the very early stage of the Solar System formation [1]. Organic matter and water-related minerals in the sample may be related to the volatiles that were delivered to the proto-Earth as source materials of ocean and life [1].

Initial description of retuned samples in the nitrogen-filled clean chamber system at the JAXA's curation facility showed that the samples well represent the Ryugu surface material, observed by Hayabusa2 [2, 3], from spectroscopic and morphological perspectives [4-6]. A fraction of Ryugu sample (0.3 g in total) has been being investigated by the Hayabusa2 initial analysis team to characterize them chemically, mineralogically, and petrologically and to understand the origin and evolution of Ryugu and the Solar System. The initial analysis team consists of six sub-teams that analyze the samples with different approaches and focuses: Chemistry, Petrology and mineralogy of coarse grains, Petrology and mineralogy of fine grains, Volatiles, Organic macromolecules, and Soluble organic matter. This presentation will give an overview of the initial analysis results of Ryugu sample on behalf of the Hayabusa2 project.

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KEYWORDS C-type asteroid, chondrite, Hayabusa2, Solar System

Division F
#985

YORP-driven structural and rotational interactions of irregularly shaped rubble pile asteroids

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Asteroids with 1 km in diameter or less are generally rubble piles and gradually vary their spin states due to multiple processes within their lifetime. Among such processes is the YORP effect, which changes an asteroid's spin due to solar radiation-driven torques and depends on its irregular shape. When an asteroid under YORP spins up and eventually approaches its spin limit, the internal structure cannot keep its original shape and gradually deforms, changing the shape. Here, we employ a finite-element model technique for combining the calculations of YORP acceleration and shape deformation to characterize how these processes correlate. The YORP acceleration is computed by solving the 3-D heat balance to determine thermal conditions and determining radiation and reflectance to compute thermal torques. On the other hand, shape deformation is simulated by considering 3-D topographic diffusion on an irregular shape, implicitly assuming that landslides are the main contributor to deformation. These calculations are performed iteratively to see how YORP and shape depend on each other. We apply this technique to top-shaped bodies (Ryugu and Bennu), a contact binary (Itokawa), and an irregular shape (Golevka). From a macroscopic view, our results suggest that deformation is necessary at some level to induce enough geometric alteration to have a non-negligible change in YORP. Such trends depend on the shape types and size. This work complements earlier work (Cotto-Figueroa and Statler, 2015) to explore this issue further.

Reference:

Cotto-Figueroa and Statler (2015), "Coupled spin and shape evolution of small rubble-pile asteroids: Self-limitation of the YORP effect," The Astrophysical Journal, 803, 1, 25, doi:10.1088/0004-637X/803/1/25.

KEYWORDS Asteroids: Shape, Asteroids: Rotation, Asteroids: YORP

Division F

#860

Numerical investigation of how (486958) Arrokoth's structure did respond to the sky impact

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The cold classic Kuiper belt object (CCKBO) Arrokoth, explored by NASA's New Horizons spacecraft, has a contact binary shape – two lobes connected with a narrow contact region (called 'neck'). This structure condition is considered to be formed via a slow and tidal merger of a binary planetesimal. One geological feature identified in New Horizons images is that Arrokoth has the largest crater-like feature on the small lobe. This region is named 'sky' and is probably an impact crater because of its bowl shape. Given that the sky is 7-km wide and 1-km deep, which takes up ~7% of the size of the small lobe, we anticipate that the structurally weak neck region could be affected by the substantial structural disturbance if the impact occurred after the bilobate shape had formed.

In this study, we analyze how the bilobated shape of Arrokoth responded to the sky impact by numerically investigating its time-varying stress field after the impact. We use a pi-scaling law to estimate the impulse velocity felt by the small lobe given the final crater size of 7 km. The bulk density of Arrokoth is set as 2.0 - 5.0 g/cc, which implies high porosity for this body. The projectile is also assumed to have the same material as the target body. We then measure the stress field across the Arrokoth structure by applying the impulse velocity into the small lobe. The stress field is computed from our Finite Element Model (FEM), which is developed to calculate the stress distribution when the body rotates uniformly as its initial condition. Our preliminary results show that Arrokoth's neck region could likely have a few kilopascals stress variations when the small lobe has the velocity impulse of 1 m/s. This stress variation may reach its failure limit of a weak structure like Arrokoth, which is a highly porous body possibly having lower strengths, although the impact mechanism of the porous icy body is still not well explored yet. This investigation not only allows understanding how the bilobate shape structurally responds to impacts but also further provides insight into the collisional evolution in the Kuiper belt when considered a large fraction of KBOs is likely to contact binary.

KEYWORDS KBO, Collisional process

Division F

#1280

Comparison of Stratified and Effective Rheological Models For Icy Worlds

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We compare multilayered and effective rheological models for the dynamics of extended deformable bodies evolving under the influence of gravitational forces. A typical case is that of a satellite with icy crusts, subsurface oceans, molten mantles and solid cores orbiting a giant planet in either our solar system or in exoplanetary systems. The goal is to explore the limits of applicability of effective rheological models to stratified icy satellites.

KEYWORDS Rheology, Icy worlds, Subsurface oceans

e-Posters

Division F

#3376

Comet P/2003 T12 (SOHO) as a possible fragment of 169P/NEAT or a common ancestor

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We present the final results of our study on the origin of the comet P/2003 T12 (SOHO) as a product of the fragmentation of 169P/NEAT, motivated by the great orbital similarity that both Jupiter family comets present today (Fernández & Sosa 2015). We studied the dynamical evolution of both comets for 10000 years towards the past using the Mercury orbital integrator (Chambers 1999). We found that their dynamical evolution is stable for almost the first 2000 years into the past, with four simultaneous well defined minima of their relative distance and velocity within that period. We studied possible fragmentation events at the epochs of these minima by generating thousands of fictitious fragments at different speeds relative to the parent body at each epoch, and analying the similarity of their orbital evolution with that of C/2003 T12 from the hypothetical epoch of fragmentation towards the present. We applied several criteria for orbital similarity (e.g. Rozek et al 2011, Kholshevnikov et al 2016). Our main conclusion is that the fragmentation of comet 169P (or of a common parent body for both comets) that generated P/2003 T12 could had happened about 1700 years ago, which is consistent with other works (e.g. Jennisken 2006, Jenniskens & Vauballion 2010).

KEYWORDS Jupiter family comets, Near-Earth asteroids, Dynamics

Division F

#3107

Migration of bodies ejected from the Earth into heliocentric orbits

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Migration of bodies ejected from the Earth into heliocentric orbits was studied for several values of an ejection angle iej (measured from the surface plane) and a velocity vesc of ejection (11.22≤vesc≤16.4 km/s). The bodies started their motion from the point of Earth's surface located most far from the Sun. The gravitational influence of the Sun and all eight planets was taken into account. Bodies that collided with planets or the Sun or reached 2000 AU from the Sun were excluded from integration. The motion of bodies was studied during dynamical lifetime Tend of all bodies which was about 200-350 Myr. The fraction pE of bodies collided with the Earth didn't exceed 0.02 and 0.12 during time T=1 Myr and T=10 Myr, respectively. For T=10 Myr, the ratio of the values of pE at iej=45o to those at iej=30o varied between 1.2 and 2.4. It was mainly greater at greater vesc. For T≥100 Myr, the values of pE were in the range 0.1-0.2 and were typically greater by a factor of 1.5-2 than at T=10 Myr. The fraction pej of bodies ejected into hyperbolic orbits during Tend typically did not exceed 0.1. The values of pej were mainly greater for greater vesc. About 1/3-1/2 of bodies collided with the Sun. The probability of a collision of a body with Venus was about 0.2-0.25. The probability of a collision of a body with Mercury and Mars did not exceed 0.08 and 0.024, respectively. The ratio of probabilities of collisions of bodies with the Earth and the Moon was mainly about 20-30, and the values of the probability with the Moon in its present orbit were often about 0.006. Such values are not enough for understanding the present fraction of iron in the Moon and testify that a large Moon embryo formed close to the Earth. The studies were supported by government-financed research project for the Vernadsky Institute (falls of bodies onto planets) and by the project 21-17-00120 of the Russian Science Foundation (the studies of falls of bodies onto the Moon and its growth).

KEYWORDS Earth, Moon, planets, bodies, migration, collisions

Division F

#2904

TESS discovery of a sub-Neptune orbiting a mid-M dwarf TOI-2136

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The Transiting Exoplanet Survey Satellite is performing an all-sky survey and targets bright nearby stars, providing an exciting opportunity to discover small transiting planets around M dwarfs. The TESS Primary Mission has already yielded the detections of several such systems. Some of those planets also have precise mass constraints through spectroscopic measurements thanks to the brightness of their host stars. Here we present the discovery and follow-up observations of a transiting sub-Neptune around the nearby M4.5V dwarf, TOI-2136. We present RV measurements from SPIRou along with a series of additional time-series observations including ground-based photometry and high resolution images that allow us to confirm that the TESS signal is due to a transiting planet. The small size and quiet nature of the host star as well as its brightness in the NIR make TOI-2136 b amenable to be further observed by most JWST modes for studying atmospheric compositions.

KEYWORDS planetary systems, planets and satellites, TOI-2136, TESS

Division F

#2910

State-of-the-art of ground and space-based instruments mainly contributed to "Earth-type" planets discovery : What's the Next ?

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The study of exoplanets is driven in part by our desire to better understand the origins of life and our place in the universe. Life as we know it requires a few crucial ingredients that one would expect to find on habitable exoplanets. In the last few years, some "Earth-type" planets have been found within the habitable zones around nearby stars. Here we present a state-of-the-art of ground and space-based astronomical instruments mainly contributed to "Earth-type" planets discovery. A statistical study on the properties of "Earth-type" planets detected by these instruments is also presented. This statistical data can then be used to guide follow-up studies of the individual planets and to assist in designing efficient finding or characterization missions based on different techniques of observations. After candidate planets are found, the next logical step is to obtain spectra of the planetary atmospheres, looking for signatures related to life on Earth, such as water and oxygen. This is not always feasible, and represent the greatest challenge for the success of such a mission.

KEYWORDS Exoplanets, Planetary atmospheres, Transmission spectra

Division F

#1735

High-resolution spectral observations of meteors

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The composition of meteoroids is of great interest, particularly because of their links to their parent asteroids and comets. The Canadian Automated Meteor Observatory (CAMO) includes a tracking system which can image mm- to cm-sized ablating meteoroids with meter-scale resolution. More than 90% of meteoroids fragment as they ablate (Subasinghe et al., 2016), either into resolvable fragments or as a long tail of shed material.

A new tracking system has been added to CAMO, which uses a diffraction grating to record spectra at video rates. The system uses an extended-blue image intensifier, allowing lines down to 390 nm to be observed. It is driven by the same wide-field observations as the non-spectral system, so each observed meteor is also captured from two stations in the non-spectral systems. This new system should make it possible to look for inhomogeneities in small meteoroids, as well as differences in emission between the head and wake of meteors.

Subasinghe, D., Campbell-Brown, M., Stokan, E. (2016) MNRAS 457, 1289.

KEYWORDS meteors

Division F

#1655

Study of Pluto's atmosphere based on 2020 stellar occultation light curve results

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On 6 June 2020, Pluto's stellar occultation was successfully observed at a ground-based observatory in Iran, and Pluto's atmospheric parameters were investigated. We used an atmospheric model of Pluto, assuming a spherical and transparent pure N2 atmosphere. Using ray-tracing code, the stellar occultation light curve was satisfactorily fit to this model. We found that Pluto's atmospheric pressure at the reference radius of 1215 km was 6.72 ± 0.48 μbar in June 2020. Our estimated pressure shows a continuation of the pressure increase trend observed since 1988 and does not confirm the rapid pressure decrease tentatively reported in 2019. The pressure evolution is consistent with a seasonal transport model. We conclude that the N2 sublimation process from Sputnik Planitia is continuing. This study's result is shown on the diagram of the annual evolution of atmospheric pressure.

KEYWORDS Astronomy, Planets, Pluto, solar system

Division F

#258

Numerical Estimation of tidally induced resurfacing on Apophis during the 2029 Earth encounter

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On April 13, 2029, potentially hazardous asteroid (99942) Apophis will have a close Earth encounter with perigee less than six Earth radii. This close encounter is enough to change Apophis' orbit and rotation state, and we also expect Apophis' surface condition may be affected by the Earth's tidal forces (so-called tidally induced resurfacing). The tidal effect from Earth encounters has been considered one factor in revealing S-type asteroids' fresh surface underneath the weathered surface layers by a space weathering process. This hypothesis was supported by some statistical studies but never detected. We believe that the 2029 Apophis' Earth encounter would be a golden opportunity to learn the correlation between the tidal effect and surface degradation.

This study numerically investigates the range of surface grain motions driven by the tidal forces from Earth on Apophis using a dynamic model and discrete element method (DEM). The dynamic model simulates the orbital and spin evolution of Apophis 3 hours before and after the closest encounter and computes the surface slope evolution on the current best-fit shape model. The surface slope defines how a surface element normal is tilted to the body center direction, and its evolution indicates the change in slope in the direction of the net force (gravity, tidal, and rotational forces) acting on each facet. Accelerations computed by the dynamic model for selected surface elements are uniformly applied to a periodic patch of polydisperse spherical grains in DEM simulations over the same encounter window. The scale of the regolith motion from the DEM simulations is measured and associated with the slope variations measured in the dynamic model to extrapolate statistics for estimating the resurfacing scale of the entire surface during the close approach. This investigation can inform the degree of potential resurfacing on Apophis and further provide insight for mission concepts like KASI's Apophis Rendezvous Mission.

KEYWORDS Asteroids, PHA, NEA, Apophis

e-Talks

Division F

#3070

Motion of planetesimals in the Proxima Centauri planetary system

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The Proxima Centauri planetary system consists of planet c (with a semi-major axis a=1.5 AU and mass m=7mE, where mE is the mass of the Earth) and inner planets b (a=0.05 AU, m=mE) and d (a=0.03 AU, m=0.3mE). The motion of planetesimals with initial semi-major axes ao between 0.9 and 2.3 AU was studied. Their initial eccentricities eo equaled to 0.02 or 0.15. It was obtained that the probability of a collision of a planetesimal during its dynamical lifetime with planet c was about 0.05 at 1.1≤ao≤1.2 AU, 0.4-0.55 at 1.2≤ao≤1.7 AU, 0.3 at 1.7≤ao≤1.8 AU, 0.02 at 1.8≤ao≤1.9 AU for eo=0.02. It was about 0.1 at 1.0≤ao≤1.1 AU, 0.3 at 1.1≤ao≤1.9 AU, 0.04 at 2.0≤ao≤2.2 AU for eo=0.15. Most collisions were during the first 10 Myr. For eo=0.02, the ratio of the number of planetesimals collided with planet c to that ejected into hyperbolic orbits was about 2 at 1.1≤ao≤1.2 AU, 1.2 at 1.2≤ao≤1.4 AU, 0.85-1 at 1.4≤ao≤1.6 AU, 1.3 at 1.6≤ao≤1.7 AU, 0.5 at 1.7≤ao≤1.8 AU, 0.2 at 1.8≤ao≤1.9 AU. For eo=0.15, this ratio was about 0.9 at 1.0≤ao≤1.2 AU, 0.5-0.6 at 1.2≤ao≤1.4 AU, 0.4 at 1.4≤ao≤1.8 AU, and 0.05 at 2.0≤ao≤2.3 AU. At time T=100 Myr the fraction of initial planetesimals that were left in elliptical orbits was not more than 0.06 at 1.2≤ao≤1.7 AU and 2.0≤ao≤2.1 AU for eo=0.15, and it was not more than 0.25 at 1.2≤ao≤1.8 AU for eo=0.02. The probability of a collision of a planetesimal from the vicinity of planet c with planet b was ~10-4-10-3. Similar values were obtained for the probability of a collision of a planetesimal with exoplanet d. Such probabilities are greater than the probability of a collision with the Earth of a planetesimal migrated from the zone of the giant planets in the Solar System. The work was supported by Vernadsky Institute (migration of icy planetesimals to inner exoplanets) and by the grant 075-15-2020-780 of Ministry of Science and Higher Education of the Russian Federation (formation of exoplanets and ejection of planetesimals into hyperbolic orbits).

KEYWORDS Proxima Centauri planetary system, planetesimals, exoplanets, collisions

Division F

#2184

Expanding the applicability and accessibility of NASA's Meteoroid Engineering Model

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NASA's Meteoroid Engineering Model (MEM) describes the meteoroid environment in the inner solar system and is primarily used to assess the risk posed to spacecraft by particle impacts. Historically, MEM has been restricted to locations between 0.2 and 2 au from the Sun and within a few degrees of the ecliptic plane, and has most frequently been distributed as a Windows desktop application. We have recently migrated MEM to a web application and are in the process of removing the near-ecliptic restriction. These changes will make MEM both available to a broader range of users and useful for a broader range of applications; future possible applications include the analysis of solar observation missions and studies of impacts on inclined natural bodies.

KEYWORDS meteoroids

Division F

#1800

The historic stellar occultations by the sub-km sized Near-Earth Asteroid (99942) Apophis

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The powerful method of stellar occultations is an unbeatable technique uniquely approaching, in some aspects, the performances of planetary space missions. Moreover, stellar occultations allow high-accuracy astrometry measurements with uncertainties (in the tangential direction) ranging from a few mas to a fraction of mas for Near-Earth Asteroids (NEAs). Before March 2021, (3200) Phaethon (about ~5km) was the only NEA (of diameter < 10 km) for which an occultation was recorded in 2019.

However, thanks to the accuracy of Gaia stellar catalogues and a "last-minute" refinement of Apophis' orbit using radar measurements (uncertainties of a fraction of mas in the radial direction), from Goldstone radio telescopes, we successfully predicted a series of successful occultation events. These radar measurements took advantage of Apophis' encounter with Earth on March 6th, 2021 at 01:06 UT, when it was at its closest at ~43.8 lunar distances from Earth.

Several occultations were predicted in the weeks following Apophis' close encounter, the first of which was observable from the USA on March 7th, 2021. This occultation of the star NY Hydrae (magnitude 8.4) by Apophis lasted for 0.1s on the longest recorded chord.

Despite of the sanitary travel restrictions, several observers (most of whom members of the International Occultation Timing Association, IOTA) were deployed along our predicted occultation path. Other occultation opportunities in Europe couldn't be attempted because of the heavier travel restrictions.

Nonetheless, we were able to record a few successful events on March 22nd, April 4th, 10th, 11th, and May 6th events, which recorded 3, 1, 3, 2, 3, and 4 positive occultation chords, respectively.

We will present here the first results of the first ever recorded occultation by a sub-km sized asteroid, not the least of which is (99942) Apophis. These occultations allow us to better constrain the size of Apophis and to refine the measurements of its Yarkovsky acceleration.

KEYWORDS Near-Earth Asteroids: Apophis, Observational methods: stellar occultation

DIVISION G

Stars and Stellar Physics

Invited & Contributed Talks

Division G

#994

Towards a more realistic description of Wolf-Rayet atmospheres

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As the direct progenitors of stellar-mass black holes and important contributors to galactic ionization and ISM enrichment, Wolf-Rayet (WR) stars cover a small but impactful portion of the massive stars. Their strong radiation acts as the main driver of their powerful stellar wind, which effectively pushes away the outer layers of the star. This causes the WR star to be embedded in an optically thick cloud of wind material, obscuring the star itself from sight. Instead, the light that can usually be observed originates in the stellar wind of the star. Hence, a realistic modelling of the wind is of paramount importance in order to understand the propagation of light and, eventually, to calculate the emergent WR-star spectrum.

To construct these models, typically the so-called beta-velocity law is used to describe the behaviour of the wind. Using this pre-described velocity field, several discrepancies have accumulated, the most striking of which is the large difference between deduced radii and expectations from stellar evolution modelling. In our study, we quantified this problem by computing and analysing WR-star winds, adopting several different wind velocity fields for stellar models with typical parameters. Our results demonstrate that the different velocity fields have a profound impact on the spectrum of the star, to the extent that we can cover almost the entire range of WR spectral subclasses by only using different velocity fields. To overcome these discrepancies, we turn to improved velocity descriptions obtained by consistently solving the hydrodynamic equation of motion. In this talk, we will present the spectral imprint of different assumptions for pre-described WR wind velocity fields, discuss the necessity for UV spectra to get a proper handle on WR wind parameters and give first results of our hydrodynamically consistent modelling of WR-star atmospheres.

KEYWORDS Wolf-Rayet, stars:atmospheres, stars:winds, stars:mass-loss

Division G

#2110

A New Monte-Carlo Radiative Transfer Simulation of Cyclotron Resonant Scattering Features

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We present a new Monte-Carlo radiative transfer code, which we have used to model the cyclotron line features in the environment of a variable magnetic field and plasma density. The code accepts an input continuum and performs only the line transfer by including the three cyclotron resonant processes (cyclotron absorption, cyclotron emission, cyclotron scattering).
Subsequently, the effects of gravitational red-shift and light bending on the emergent spectra are computed. We have applied our code to predict the observable spectra from three different emission geometries; 1) an optically thin slab near the stellar surface, 2) an accretion mound formed by the accumulation of the accreted matter, 3) an accretion column representing the zone of a settling flow onto the star. Our results show that the locally emergent spectra from the emission volume are significantly anisotropic. However, in the presence of strong light bending the anisotropy reduces considerably. This averaging also drastically reduces the strength of harmonics higher than a second in the observable cyclotron spectra. We find that uniform field slabs produce line features that are too narrow, and mounds with large magnetic distortions produce features that are too wide compared to the average widths of the spectral features observed from various sources. The column with a gently varying (dipole) field produces widths in the intermediate range, similar to those observed.

KEYWORDS Neutron Star, Rediative transfer, cyclotron line, HMXB

Division G

#2856

Radioactive elements with long and short decay times in stellar atmospheres

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Only radioactive elements with long decay times, namely thorium and uranium, are usually investigated in stellar atmospheres.
We analyzed the conditions required for stellar age determinations and found the necessity of taking into account additional physical phenomena, namely nonuniversality of r-process and the accretion of interstellar and circumstellar hydrogen and helium on the atmospheres of normal stars.
We analyzed spectral lines of several radioactive elements with short decay times – plutonium and actinium in the atmospheres of several stars. We confirmed wavelength coinsidence for plutonium in Przybylski's star and determine the abundances of actinium in the atmospheres of Przybylski's star and several other objects.
Note that the longest decay times of plutonium and actinium isotopes are near 80 millions years and 22 years respectively.
The detection of spectral lines of these elements points the existence of unknown physical process in stellar atmospheres.

KEYWORDS stars:abundances, stars:radioactive elements, stars:atmospheres, r-process, accretion

Division G

#2797

Magnetic pressure a necessary contribution to pressure in stellar atmospheres modeling.

Innocenza Busa[1]

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The atmosphere of many stars (active, flare, chemical peculiar stars) is permeated by magnetic fields that emerge from deeper layers. With increasing height the atmospheric structure is more greatly influenced by magnetic fields, since the energy density of the magnetic fields should fall off more slowly than the energy density of the gas.

Magnetic field acts in the degeneration of electronic levels giving rise to zeeman splitting, furthermore it can also be described in terms of magnetic pressure which modify the hydrostatic equilibrium.

Therefore, magnetic pressure has to be taken into account in the computation of the total pressure and is not. This lack implies that electron densities and the hydrogen populations obtained from imposing Hydrostatic Equilibrium in semiempirical atmospheric models (e.g. Solar Val~3c model) are not correct and a true improvement can be obtained introducing the magnetic field contribution. I show the change of the Solar Val~3c model when introducing the solar magnetic field contribution, suggesting possible observations that would allow to verify whether the atmospheric structure obtained describes the solar atmosphere more correctly than classical solar model like Val 3c.

KEYWORDS modeling atmosphere, radiative transfer, magnetic field

Astronomy for All
Busan 2022

Division G

#2712

PhD Prize Talk: Characterization of solar-type stars and study of their internal magnetic fields along the evolution: Machine learning for asteroseismology and theoretical constraints for internal magnetic fields

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Space missions Kepler, TESS and soon PLATO allow the observation of millions of stars. In this thesis, we are particularly interested in red giants (evolved solar-type stars). One of the legacy results of the Kepler mission is the interestingly low rotation rate of the core of subgiant and red giant (RG) stars, which is about 10 times lower than predicted with the current theory for the transport of angular momentum by purely hydrodynamical mechanisms. This discrepancy points out an order of magnitude issue concerning the understanding of the evolution of the stellar angular momentum in evolved Solar-like stars, a very ubiquitous problem shared by stars of all types and ages.

In this context, high-precision in the observables (such as surface gravity) is needed for stellar models results to be reliable. By combining classical asteroseismology and innovative tools such as machine learning, we first focus on the better characterisation of the surface gravity for solar-type pulsators, including those that do not present detectable oscillations in their spectra. With Random Forest machine learning algorithms, solar-type stars observed by Kepler and TESS are classified among the different type of pulsating stars, and surface gravities of stars observed by Kepler are estimated directly from the global power of the granulation with very small uncertainties.

With the sample of well-characterised stars, we then theoretically seek for a missing process taking place inside the core of RG to efficiently extract angular momentum from the core to the surface. Internal magnetic fields are one amongst the most serious candidates that are currently studied to solve the problem, and their signature should be visible in asteroseismic data. To unravel which constraints can be obtained from observations, we theoretically investigate the effects of a plausible mixed axisymmetric magnetic field with various amplitudes on the mixed-mode frequencies of red giants. Applying a perturbative method, we estimate the magnetic splitting of the frequencies of simulated mixed dipolar modes that depends on the magnetic field strength and its configuration. Finally, we infer an upper limit for the strength of the field and the associated lower limit for the timescale of its action to redistribute angular momentum in stellar interiors.

KEYWORDS Stars, Magnetism, Asteroseismology, Evolution, Machine Learning

Division G

#1231

On convection and gravity waves in F stars

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We present a recent numerical and theoretical study on convection and gravity waves in F stars.

Based on a series of 3D hydrodynamical simulations of F-type stars computed with the ASH code including both a radiative interior and a convective envelope, we assess how convection establishes large scale mean flows in such stars and how the pummeling of turbulent plumes generates internal gravity waves deep inside the star. We study the properties of angular momentum transport by Reynolds stresses in the convective envelope and the excitation and propagation of the internal waves.

We find that a wide spectrum of gravity waves is excited with a maximum power at intermediate degree ell values.

When introducing rotation, we find that the rotational splitting of the g-modes can be easily computed and that only for high radial orders are the rotational values inferred close to the real rotation rate of the model, as expected from the linear theory of oscillations.

KEYWORDS F stars, internal waves, convection, asteroseismology

Astronomy for All
Busan 2022

Division G

#612

Shear instabilities and turbulence in radiation zones of rotating stars

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Turbulent transport of momentum and chemicals in the interior of stars is one of the key physical processes that affect the long-term evolution of stars. While our knowledge of the internal structure and evolution of rotating stars has been dramatically broadened by the advancement in asteroseismology, we still do not fully understand the mechanisms on how the angular momentum and chemicals are effectively transported. Among several candidates such as magnetic fields or internal gravity waves, we focus on the fundamental hydrodynamical mechanism: turbulent transport induced by shear instabilities due to differential rotation in the stellar interior. In stellar radiation zones, the interplay between the differential rotation in the vertical (radial) and horizontal (latitudinal) directions, stable stratification in the vertical direction, and fast thermal diffusion is crucial. While previous studies have investigated shear flows with few effects such as stratification/thermal diffusion or stratification/rotation with the traditional f-plane approximation which is only valid at the poles, we study the complete effects of the stratification, diffusion, and rotation with the full Coriolis acceleration on the horizontal and vertical shear instabilities. The full Coriolis acceleration is in particular important to understand the turbulent dissipation at any latitude in the stellar radiation zone. By considering a canonical example of hyperbolic tangent shear flow profiles, we perform a linear stability analysis and investigate two types of instabilities: the inflectional and inertial instabilities. With detailed numerical and theoretical results, we will explain how the stable stratification and thermal diffusion affect the two instabilities, and more interestingly, how the full Coriolis acceleration destabilizes the shear flows. We will also discuss nonlinear effects leading to turbulence and how the results can be used to develop new turbulence models, which can be applied to stellar evolution simulations.

KEYWORDS Stars, Radiation zones, Rotation, Shear flow, Instabilities, Turbulence

Division G

#2310

A double magnetic dynamo in cataclysmic variables

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With an updated equation of state implementation in the Cambridge stellar evolution code STARS, we model the secular evolution of cataclysmic variables (CVs) using a double dynamo (DD) model wherein there is an interplay between two alpha-Omega dynamos, one in the convective envelope and the other at the boundary of a slowly rotating shrinking radiative core and the growing convective envelope. We confirm that this model provides a physical formalism for the interrupted magnetic braking paradigm as well as a mechanism for extra angular momentum loss below the period gap. We construct the relative probability distribution of orbital periods using the white dwarf distribution in CVs and find that our model reproduces the period gap and the observed period minimum spike in CV distribution. We find good agreement of our modelled systems with those of empirical models and with observational data. We then look at how the convective dynamo in the DD model may affect the evolution of AM CVn stars.

KEYWORDS stars, binary stars, magnetic dynamo

Division G

#3023

First Detection of Gravity Modes in RR Lyrae Stars

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In this Invited talk, I report the first detection of gravity modes in RR Lyrae stars. Thanks to Photometer AntarctIca eXtinction (PAIX), the first Antarctic polar photometer. Unprecedented and uninterrupted UBVRI time-series photometric ground-based data are collected during 150 days from the highest plateau of Antarctica. Despite great ground-based and space observations, the oscillation modes whose restoring force is gravitation have been actively searched for several decades. The detection of any gravity wave signal in the Sun, the most observed and best known star to human beings, is still a highly contentious issue today. PAIX light-curve analyses reveal an even richer power spectrum with mixed modes in RR Lyrae stars. Lower and higher frequencies and harmonics linearly interact with the dominant fundamental radial pressure mode and its second and third overtone pressure modes, and Half-integer frequencies as well. However, the most striking finding is the direct detection of gravity waves. I discuss a possible mechanism for the excitation of gravity modes in RR Lyrae stars and I show that RR Lyrae stars are simultaneously g-mode and p-mode pulsators. Such a detection makes RR Lyrae stars very challenging stellar objects, and provides their potential to undergo at the same time g and p modes toward an advancement of the theory of stellar evolution and a better understanding of the universe.

KEYWORDS gravity modes, pulsating stars, RR Lyrae stars, Antarctica Photometer, Excitation of gravity modes, Stellar evolution, frequency spectra

Division G

#1527

Accretion bursts in high-mass protostars

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Recent observations of high-mass young stellar objects (HMYSOs) with masses $M_* \geq 10 M_\odot$ uncovered outbursts with accretion rates exceeding ~10–3M⊙ yr–1. We utilise 1D time-dependent models of protoplanetary discs around HMYSOs to study burst properties. We find that discs around HMYSOs are much hotter than those around their low-mass cousins. As a result, a much more extended region of the disc is prone to the thermal hydrogen ionisation and magnetorotational (MRI) activation instabilities. The outbursts triggered by these instabilities, however, always have too low accretion rates and are one to several orders of magnitude too long compared to those observed from HMYSOs to date. On the other hand, bursts generated by tidal disruptions of gaseous giant planets formed by the gravitational instability of the protoplanetary discs yield properties commensurate with observations, provided that the clumps are in the post-collapse configuration with planet radius Rp≥10 Jupiter radii.

Outflows and radiation feedback is a well-known challenge to formation of young massive stars. Disc mediated accretion is one way which may reduce these feedback effects substantially. 3D simulations show that these discs fragment onto multiple self-gravitating objects that migrate towards the central massive star rapidly, possibly merging with it. However, numerical limitations so far precluded resolving the inner tens of AU in such simulations. We model the disc and migrating object dynamics in this innermost region, aiming to determine their fate. We post-process results of a previous 3D simulation of a high-mass young stellar object (HMYSO) disc growth with a 1D code that couples migrating objects to the disc evolution self-consistently. We find that the fate of migrating objects depends strongly on the physical size of the HMYSO. For compact HMYSOs, with radii smaller than ~10 AU, migrating objects are tidally disrupted, producing powerful disc mediated bursts similar in nature, but much brighter than the FU Ori outbursts of low-mass YSOs. These bursts may be so bright as to exceed the HMYSO Eddington limit, ensuring that a good fraction of the disrupted object mass is launched into powerful outflows. On the other hand, migrating objects end up merging with HMYSOs that are bloated to size $R \geq 100 R_\odot$.

KEYWORDS Protoplanetary disks, Star formation

Division G

#2852

THE FIRST PHOTOMETRIC STUDY OF AH MIC CONTACT BINARY SYSTEM

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The first multi-color light curve analysis of the AH Mic binary system is presented. This system has very few past observations from the southern hemisphere. We extracted the minima times from the light curves based on the Markov Chain Monte Carlo (MCMC) approach and obtained a new ephemeris. To provide modern photometric light curve solutions, we used the Physics of Eclipsing Binaries (Phoebe) software package and the MCMC approach. Light curve solutions yielded a system temperature ratio of 0.950, and we assumed a cold star-spot for the hotter star based on the O'Connell effect. This analysis reveals that AH Mic is a W-subtype W UMa contact system with a fill-out factor of 21.3% and a mass ratio of 2.32. The absolute physical parameters of the components are estimated by using the Gaia Early Data Release 3 (EDR3) parallax method to be $Mh(M_\odot) = 0.702(26)$, $Mc(M_\odot) = 1.629(104)$, $Rh(R_\odot) = 0.852(21)$, $Rc(R_\odot) = 1.240(28)$, $Lh(L_\odot) = 0.618(3)$ and $Lc(L_\odot) = 1.067(7)$. The orbital angular momentum of the AH Mic binary system was found to be 51.866(35). The components' positions of this system are plotted in the Hertzsprung-Russell (H-R) diagram

KEYWORDS

Division G

#2745

Decoding the white dwarf fossil record

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White dwarf stars are tracers of stellar and galactic evolution, as well as unique windows into the composition of rocky exoplanetary bodies. To access this fossil record, accurate models of their atmospheres and interiors are required. But the peculiar conditions encountered in white dwarfs pose significant challenges to their modelling. The oldest white dwarfs have liquid-like atmospheres with uncertain constitutive physics; their dense interiors eventually freeze into a solid state and are chemically fractionated; and their compositions depend on the details of convective boundary mixing during previous evolutionary phases. In this talk, I will review recent progress on physics models of white dwarfs obtained by applying advanced theories of dense matter, performing large-scale computational simulations, and carrying out laboratory experiments under extreme conditions. I will also discuss how those advances allow to better explain observations and enable new exciting applications of white dwarfs as probes of planetary, stellar, and galactic evolution.

KEYWORDS Stellar atmospheres, Stellar evolution, White dwarfs, Plasma physics, Cosmochronology, Planetary systems

Division G

#2363

Disentangling the mysteries of single pulses from the Crab pulsar

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After more than 50 years of intense studies the mechanism behind the observed radio emission of fast rotating and very highly magnetized neutron stars known as pulsars is not understood.

The Crab pulsar belongs to the early discovered pulsars, but its emission characteristics at radio wavelengths challenge currently existing models. In contrast with other pulsars it shows seven average emission components with a frequency dependent occurrence. Besides, it is a source of very bright single pulses that were classified as giant pulses. Both observed characteristics cannot be explained with currently existing models.

We present the results of an extensive study of single radio pulses from the Crab pulsar observed in a frequency range from 2 to 6 GHz with the Extended Very Large Array. We determine the dispersion measure of single pulses at a time resolution of 1 microsecond using cross correlation functions and study the dependance of dispersion meassure and polarization properties on brightness and emission components.

KEYWORDS pulsar, crab pulsar, dispersion measure, radio giant pulses, single pulses, high frequency interpulse, cross correlation

Division G

#2598

Fully relativistic global simulation of tidal disruption event

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Tidal disruption events (TDEs) occur when stars are tidally disrupted by supermassive black holes. Approximately 100 tidal disruption event (TDE) candidates have been observed. In the near future, the number will grow dramatically with detections by the ongoing and upcoming surveys (e.g., eROSITA and LSST). However, the mechanism responsible for the luminosity and the shape of the light curve of observed TDEs is poorly understood. For reliably classifying transients and deciphering their emission features to unveil the nature of the main source and surroundings, it is crucial to understand the dominant emission mechanism of the events. The only way to fully investigate the long-term evolution of the debris and the emission mechanism is to perform global simulations with astrophysically realistic initial conditions. However, performing such simulations had been considered almost impossible because of very high computational costs. Using an innovative numerical technique that I have developed, we are currently performing a fully relativistic global hydrodynamics simulation with realistic initial conditions and investigating the emission mechanism. I will present the results from our simulation and discuss their implications.

KEYWORDS black hole, star, gravity, relativity, tidal disruption even

Division G

#309

What does control the large-scale magnetic field configuration of cool stars?

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In the past decades, our knowledge of the magnetism of cool stars has largely grown thanks to the ability of tomographic imaging techniques in reconstructing surface magnetic fields. The collection of maps obtained for stars with different spectral classes, rotating rates, and age unveiled a link between the complexity of the large-scale magnetic field and the star's internal structure. Global numerical simulations succeeded at reproducing dipole-dominated or complex multipolar-dominated field topologies, suggesting that only multipolar-dominated fields would exist at Rossby numbers larger than 0.1. However, this initial description failed to explain a handful of stars with dipole-dominated magnetic fields at high-Rossby and recent studies questioned whether numerical simulations could be biased by the space of parameters explored. This talk will introduce recent propositions to overcome that bias and present new numerical simulations that are thought to be reminiscent of the outlier stars seen at high-Rossby. Finally, we will propose an energy proxy to account for this change of morphology, and we will test its ability to predict the magnetic morphology of a few M-dwarfs.

KEYWORDS Magnetic fields, stars, dynamo, numerical simualtions, convection, MHD

Division G

#1748

A Census of Thermally-Pulsing AGB stars in the Andromeda Galaxy and a First Estimate of their Contribution to the Global Dust Budget

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We present a near-complete catalog of the metal-rich population of Thermally-Pulsing Asymptotic Giant Branch stars in the northwest quadrant of M31. This metal-rich sample complements the equally complete metal-poor Magellanic Cloud AGB catalogs produced by the SAGE program. Our catalog includes HST wide-band photometry from the Panchromatic Hubble Andromeda Treasury survey, HST medium-band photometry used to chemically classify a subset of the sample, and Spitzer mid- and far-IR photometry that we have used to isolate dust-producing AGB stars. We have detected 346,623 AGB stars; these include 4,802 AGB candidates producing considerable dust, and 1,356 AGB candidates that lie within clusters with measured ages, and in some cases metallicities. Using the Spitzer data and chemical classifications made with the medium-band data, we have identified both carbon- and oxygen-rich AGB candidates producing significant dust. We have applied color--mass-loss relations based on dusty AGB stars from the LMC to estimate the dust injection by AGB stars in the PHAT footprint. Applying our color relations to a subset of the chemically-classified stars producing the bulk of the dust, we find that ~97.8% of the dust is oxygen-rich. Using several scenarios for the dust lifetime, we have estimated the contribution of AGB stars to the global dust budget of M31 to be 0.9-35.5%, which is in line with previous estimates in the Magellanic Clouds. Follow-up observations of the M31 AGB candidates with the JWST will allow us to further constrain stellar and chemical evolutionary models, and the feedback and dust production of metal-rich evolved stars.

KEYWORDS Asymptotic giant branch stars, Andromeda Galaxy, Circumstellar dust, Extreme carbon stars, Stellar mass loss, Local Group, Late stellar evolution

Division G

#2329

Kilonova and Fast Transients- An Untriggered Search

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Theories of dense matter are highly uncertain and kilonovae, resulting from neutron star merger events, are a unique laboratory for determining the equation of state of dense matter. Kilonovae are theorised to produce more than half the elements heavier than iron in the Universe and can be used to provide independent measurements on the expansion rate of the Universe, which is under debate. Short gamma ray bursts are also produced by neutron star merger events, and kilonovae can help discover much sought after off-axis gamma ray bursts and orphan afterglows. Despite immense interest and effort, only one kilonova has been spectroscopically confirmed by astronomers to date (AT2017gfo) resulting from follow-up of a gravitational wave event GW170817 coincident with a gamma ray burst.

We present the Kilonova and Transients Program (KNTraP), where we use an alternative "untargeted" or "untriggered" strategy for kilonova search. The strategy is to search for kilonova without a gravitational wave or gamma ray burst trigger. I will argue that a day-cadence two-filter observing strategy will be able to catch the fast rise, fall and colour evolution of kilonovae. Using day-turn around data processing and candidate identification, kilonova candidates can be followed-up using multi-wavelength and spectroscopic telescopes.

On behalf of the KNTraP team, I will describe and present results from the first KNTraP observing run: an 11-night observing run in February 2022 using the Dark Energy Camera (DECam) on the CTIO 4m Victor Blanco Telescope. If such an observing run were carried out during LIGO/Virgo Operational Run four (O4), then untriggered kilonova candidates can be used to back trigger sub-threshold searches for events in gravitational wave data.

KEYWORDS kilonova, transient, observational strategy, high-cadence observations, optical, neutron stars, stellar death

Division G

#1758

Unveiling effective temperatures using line depth ratios in the infrared H and K bands

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The effective temperature (Teff) is one of the most fundamental parameters of stellar atmospheres. Precise effective temperature information is needed to determine the position of stars in the Teff/log(g) HR diagram, to measure the elemental abundance, and to estimate stellar masses. Different methods are used to measure effective temperatures. One of the most sensitive Teff determination approaches developed in recent years is the Line Depth Ratio (LDR) method. So far this technique has been applied mostly to high-resolution optical spectra. Although this method is well-applied for the optical region, it has shortcomings for stars that reside in the dust-obscured regions of the Galaxy; their faint optical magnitudes often preclude acquisition of good high-resolution spectra. Therefore, we carried out a project that focuses on the need to determine effective temperatures in the less-extincted infrared spectral region. Our overall goal is to unveil the dust-obscured regions, which in turn would give us the opportunity to better understand the structure and evolution of our Galaxy.

In this study, we obtained the high-resolution infrared spectra of 110 stars using the IGRINS (Immersion Grating INfrared Spectrometer) spectrograph. IGRINS allows simultaneous coverage of the H (~1.45 - 1.80 µm) and K bands (~1.95 – 2.50 µm) with a high resolving power of R=45000. The temperature, surface gravity and metallicity range of our stars are: 3250 ≤ Teff (K) ≤ 5460, 0.20 ≤ log g ≤ 4.56, and -1.5 ≤ [M/H] ≤ 0.4. Using our sample, we were able to discover 26 pairs of lines whose central line depth ratios (LDRs) are very sensitive to Teff values. We have obtained 26 pairs of LDR-Teff correlations, many of which are in the heretofore-unexplored K band. These correlations provide an easy and convenient method to determine the effective temperatures of stars, and become essential for stars that are located in the dust-obscured regions of our Galaxy.

KEYWORDS Spectroscopy, Infrared, Stars, Fundamental parameters

Astronomy for All
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Division G

#2512

The Transients and Variable Stars Science Collaboration Roadmap Explained

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The Vera C. Rubin Observatory, formally known as the Large Synoptic Survey Telescope, is an 8.4 m telescope based in Cerro Pachon. It has a wide field of view (10 square degrees), short exposures (pairs of 15-seconds), and a sensitive camera that can observe down to 24th magnitude for single images and 27th magnitude for stacked images. The majority of the first ten years of observations will be spent on the primary survey known as the Legacy Survey of Space and Time (LSST), which will make observations of the entire southern sky approximately every three days.

The Transients and Variable Stars Science Collaboration (TVS SC) is one of eight Rubin LSST Science Collaborations. The purpose of the TVS SC is to "Explore the transient sky", one of the four primary objectives of Rubin LSST. As "Transients and Variable Stars" covers a wide range of science fields, the TVS SC is one of the largest and most diverse of all the Rubin LSST Science Collaborations. This is reflected in their roadmap, which contains contributions from over 50 TVS SC members, detailing their proposed research areas including variable events, periodic or not; explosive and eruptive transients; and geometric transients. The Roadmap is divided into three main parts, which cover the Main Survey, Mini Surveys and Deep Drilling Fields. The Main Survey is further divided into time-critical and non-time-critical science, where time-critical science depends on Broker Alerts (i.e. Supernovae) and non-time critical does not (i.e. pulsating stars). Here, we provide an up-to-date synopsis of Rubin LSST and TVS SC. We further discuss the TVS Roadmap and highlight some of the exciting new science cases that will be tackled with Rubin LSST data. Finally, we encourage you to take a look at the TVS roadmap to identify research areas where you would like to get involved.

KEYWORDS Rubin LSST, Variable Stars, Transients, Telescopes

e-Posters

Division G

#3397

Constraining the progenitor and explosion model with the early light curve of SN 2021aefx

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Despite significant efforts to identify a progenitor and explosion mechanism of Type Ia supernovae, their origin is still controversial, leading to several models to explain observational features. Since these models expect diversity in a very early phase, the early phase observation plays a key role in constraining the model. However, the lack of early phase observation of Type Ia Supernova put constraints on testing various models.

In this research, we present the earliest phase observation of SN 2021aefx as a part of the IMSNG(Intensive Monitoring Survey of Nearby Universe) project which aims to find transients by high-cadence monitoring of the nearby galaxies within 50Mpc. The explosion time is estimated as MJD 59528.07±0.1 by fitting the single power-law with exponent n of 2.35 which is 1.2 days before the first detection. With the early light curve, the template fitting with SALT2 shows the supernova is originated from Chandrasekhar mass explosion. The light curve also shows the strong U band bump in the early phase, resulting in the companion interaction model and double detonation model with a thick shell to be proposed. However, a recent study shows that the U band bump can be explained by the Doppler shift by the high velocity of the ejecta. Considering these points, we present the plausible progenitor model of SN 2021aefx.

KEYWORDS Ia supernova, progenitor, explosion model, observation

Division G

#3393

Spectral classification of selected stellar X-ray sources in the SMC

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In this poster we present a spectral classification of several X-ray sources in the Small Magellanic Cloud (SMC), that are selected with Chandra X-ray Observatory. We follow up a spectroscopic campaign with the VIsible Multi-Object Spectrograph (VIMOS) instrument on the 8.2m Very large Telescope (VLT) telescope of the European Southern Observatory (ESO) in Chile. This allows us to identify and characterize the optical counterpart of the Be X-ray Binaries (Be-XRBs) population through a conducted survey of representative regions of the SMC and X-ray luminosities down to ~ 4x1032 erg/s. Consequently, the most complete census of BeXRBs outside our Galaxy in regions with different star-formation histories will be obtained. As a result, the spectral type of the donor stars along with the mass distribution in these systems within the SMC will be determined. The importance of the above-mentioned project is evident in the ability to obtain sufficient statistics in different regions of the SMC, in order to establish and compare the donor-mass distribution in various populations for the very first time.

KEYWORDS

Division G

#3357

Multi-dimensional Cluster Analysis of Young Nearby Stars from Gaia EDR3

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Stellar groups such as open clusters, stellar associations, and moving groups have served as fundamental benchmarks for stellar astrophysics. In 150 pc from the Sun, ~30 young stellar groups have been identified. These young stellar groups can be recognized by position, velocity, and age (signs of youth). Gaia EDR3 provides unprecedentedly precise measurements of positions, parallaxes, and proper motions for nearby stars and substellar objects. With this catalogue nearly complete to nearby stellar objects, we performed cluster analysis in high-dimensional spaces of position, velocity, and age. Data scaling and parameter tuning were carefully performed and verified by detecting well-known stellar groups, including the Pleiades, the Hyades, and the Sco-Cen association. This study presents preliminary results of consistent and homogeneous cluster analysis of nearby stars.

KEYWORDS stars, open clusters, stellar associations, moving groups, Gaia EDR3, cluster analysis

Division G

#3351

Unveiling the Nature of Progenitors of Known Substructures in the Galactic Halo by Their Metal-Poor Member Stars

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We present detailed chemical abundance analysis of 11 Dynamically Associated Metal-Poor (DAMP) stars with well-known Gaia-Sausage-Enceladus (GSE), Sequoia (SEQ), Thamnos (TH), and a new substructure recently found. These targets, which were observed in Large Sky Area Multi-Object Fiber Spectroscopic Telescope (LAMOST) survey are selected by their kinematics calculated with Gaia proper motions and parallaxes. To derive the abundance of various chemical elements, we carried out a high-resolution (R ~ 40,000) spectroscopic follow-up using GEMINI/GRACES. We investigate the general nature of dwarf galaxy associated with each substructure by using both the dynamic properties of DAMP stars and their chemical characteristics, and present preliminary results.

KEYWORDS Galactic Archeology, Stellar Archeology, Milky Way, Metal-Poor Stars, High-resolution Spectroscopy, GEMINI/GRACES, Chemodynamics

Division G

#3337

Origin of Chemodynamical Discrepancies Between the Sagittarius Leading and Trailing Arms

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We present an analysis of chemical, kinematic, and orbital characteristics of Sagittarius (Sgr) tidal streams. From Sloan Digital Sky Survey, Large Sky Area Multi-Object Fibre Spectroscopic Telescope, and Apache Point Observatory Galactic Evolution Experiment data, we have identified a large number of Sgr members. For the clean sample of Sgr member stars, we used selection criteria that include distances, positions, proper motions, and angular momenta. We find that the leading arm shows systemically different characteristics in various aspects from the trailing arm and remnant of Sgr. In particular, the leading arm exhibits relatively lower eccentricity distribution than the trailing arm, which suggests that its origin may differ or it has experienced different dynamical evolution. This new development of the origin leads us to consider a new scenario of the formation of the Sgr arms, compared with the traditional one.

KEYWORDS data analysis, spectroscopic, abundances, Galaxy structure, Galaxy evolution, galaxy kinematics, Galaxy dynamics

Division G

#3248

Where Do Nitrogen Enhanced Stars in the Galactic Halo Come From?

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We present preliminary results of the analysis of dynamical properties of nitrogen-enhanced stars in the Galactic halo. The stars enhanced with nitrogen-to-iron ratio ([N/Fe]) are believed to be once members of already disrupted or existing globular clusters (GCs), and if that is the case, they may have distinctive dynamical characteristics compared to typical halo stars without much enhancement of nitrogen. From low-resolution (R ~ 2000) stellar spectra from Sloan Digital Sky Survey (SDSS) and Large Sky Area Multi-Object Fiber Spectroscopic Telescope (LAMOST), we have developed a method for determining [N/Fe] with the CN band region around 3883 Å, and classified stars into N-normal and –rich groups. We compare the two groups in terms of the metallicity distribution and kinematics to confirm whether or not they share the common origin or not. In addition, we use their dynamical properties to characterize the origin of N-rich stars, and suggest that the N-rich stars are originated from disrupted GCs that belonged to accreted dwarf galaxies such as Gaia Sausage/Enceladus, Thamnos, and Sequoia as well as those formed in situ in the Milky Way.

KEYWORDS Data analysis, Abundances, Spectroscopic, Kinematic, Milky Way stellar halo

Division G

#3240

The Nature of Heated and Accreted Stars in the Galactic Disk

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We present chemical and kinematic properties of heated (accreted) stars by (from) Gaia-Sausage/Enceladus (GSE) merger event in the Galactic disk. The heated and accreted stars are distinguished by radial velocity dispersion in the [Fe/H]-[α/Fe] plane. Generally, the accreted stars have large velocity dispersion and low-[α/Fe], while the heated stars have small velocity dispersion and high-[α/Fe]. We find that a low-[α/Fe] accreted star shows larger radial velocity dispersion than a high-[α/Fe] heated star, and the accreted and heated stars have even greater radial velocity dispersion than the typical disk stars. These results suggest that the Splash disk recently discovered consists of not only the heated in-situ disk stars, but the accreted stars from the GSE.

KEYWORDS Galaxy, disk, data analysis, spectroscopy, abundances, kinematics

Division G

#3222

Spectral features and Variability of the Thorne-Zytkow Object Candidates in SMC

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Thorne-Zytkow objects (TZOs) are expected to be formed by binary merger; however, no solid confirmation of TZOs has been made apart from one strong candidate, HV 2112 in the SMC. The challenge of searching for TZOs is that they are apparently identical to M-type red supergiants (RSGs) or very luminous AGB stars. A promising way to distinguish TZOs from them is finding chemical anomalies expected in the atmospheres of TZOs, as the candidate HV 2112 shows enhancement in Mo, Rb, Li, and Ca abundance. HV 2112 also shows double-maxima light curves with $\Delta m \sim 4.80$ and period ~ 600 days with strong Balmer emission features at its maximum, which has not been observed in RSGs. Referring to HV 2112's features, we investigate and present the chemical abundances and spectral features of TZO candidates in SMC using the MIKE spectrograph on the 6.5 m Magellan-Clay telescope and light curves from ASAS-SN. We find HV 2112 presents varying chemical abundances during its minimum and maximum, and note that another candidate, HV 859, has similar spectral features and variability to HV 2112, showing Mo and Rb enhancement, strong emission features at its maximum, and double-maxima light curves with $\Delta m \sim 4$ and period ~ 570 days, although further investigation is required.

KEYWORDS Stellar evolution, Massive stars, Spectroscopy, Chemical abundances, Variable stars

Division G

#2735

Statistical analysis of monotonic orbital-period variations for A-type W UMa binaries

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This study attempts to identify the binary parameters that are genuinely associated with the mass transfer (MT) and angular momentum loss (AML) in close binaries. We first collected W UMa binaries with monotonic orbital-period variations, together with well-defined binary parameters. Assuming the monotonic variations are responsible for either of the MT or AML, their rates were calculated with the rates of change of period. After removing spurious correlations by partial regression plots, genuine correlations between the derived rates and binary parameters were identified. Moreover, power laws for the discovered correlations were derived. This presentation shows the result for A-type W UMa binaries. In the systems with negative period variations, it is found that the rate of MT from more- to less-massive components is a function of the primary radius; the rate of AML is a function of the fill-out factor. Meanwhile, in the systems with positive period variations, it is found that the rate of MT from less- to more-massive components is a function of the luminosity ratio or/and mass ratio; the mass-loss rate is a function of the secondary temperature. We also discuss possible processes occurring in the sample binaries.

KEYWORDS eclipsing binaries, period variation, W UMa binaries

Astronomy for All
Busan 2022

Division G

#2441

Physical Nature of Oscillating Eclipsing Algol System V389 Cas

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Oscillating eclipsing Algol (oEA) stars are great targets for measuring accurate stellar parameters and understanding stellar inner structure. In this study, we present the physical properties of oEA star V389 Cas based on the TESS photometric data and time-series high-resolution spectra. A total of 61 spectra were obtained at Bohyunsan Optical Astronomy Obsesrvatory (BOAO) in Korea and at the Thai National Observatory (TNO) in Thailand between 2016 and 2019. From the spectral analysis, the temperature (T1) for the more massive primary star was determined to be 7720±200 K. The physical properties of V389 Cas were determined from simultaneous analysis of our RV curves together with the TESS light curves. The results indicate that V389 Cas is a semi-detached eclipsing binary with masses of M1=2.39±0.17 $M_\odot$ and M2=0.34±0.06 $M_\odot$, and radii of R1=2.69±0.07 $R_\odot$ and R2=2.47±0.06 $R_\odot$. A total of 50 frequency signals were detected from the multi-frequency analysis of the out-of-eclipse light residuals, of which two frequencies of f2 = 28.3510 day-1 and f4 = 25.6072 day-1 can be considered as independent pulsation frequencies. The location of the primary star inside the δ Sct instability strip of the main-sequence band on the HR diagram and pulsational characteristics of the δ Sct stars indicate that V389 Cas is an oEA star, which consists of a δ Sct primary and a less massive and oversized secondary stars.

KEYWORDS binaries: eclipsing, stars: oscillations, stars: fundamental parameters

Division G

#2311

Nucleosynthesis in Thorne-Zytkow objects

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Thorne-Zytkow objects (TZOs) are proposed hybrid stars, consisting of a neutron degenerate core encased in an extended, diffuse envelope of a giant or supergiant star. The likely formation mechanism of these objects is common envelope evolution beginning the overflow of a massive RGB/AGB star on to a neutron star (NS) followed by a rapid inspiral and merging of the giant star's core with NS. The resultant TZO is then supported primarily by nuclear burning in a thin, low-mass shell, at high temperatures, just outside the core in the supergiant, high-mass case or by the release of gravitational potential energy in a region known as the knee by envelope material accreting on to the neutron-degenerate core in the giant, low-mass case. We use the Cambridge STARS stellar evolution code, with adaptive, non-Lagrangian mesh to compute self-consistent models of TZOs by extensively modifying it in order to compute the core, core-envelope interface and envelope of the models consistently. The equation of state solver is modified to raise the effective mass of electrons in the neutron degenerate regions to the neutron mass, allowing a smooth connection between the core and envelope. The proton and neutron chemical potentials are computed to obtain the density in these regions, along with appropriate neutrino-loss rates. The opacity is adjusted to model the superconductive core. With our structural chemical evolution along with a post-processing nuclear network we model detailed nucleosynthesis and dredge up to look for observable differences between TZOs and red supergiants or super-AGB stars.

KEYWORDS stars, giant stars, nucleosynthesis

Division G

#2085

Measurements of mass-accretion rates for T Tauri stars based on LAMOST low-resolution spectroscopic and TESS data

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We present the first mass-accretion rate measurements for 12 T Tauri stars with the spectral types from late—K to mid—M types based on the LAMOST low-resolution spectral data and TESS lightcurve if available using H-alpha emission luminosity and luminosity outburst. From the spectral measurement, the mean mass—accretion rate measurement of our targets is $2.81\times10^{-9}M_\odot/yr$. CoKu Tau 1, an M0 star, has the lowest mass—accretion rate of $5.66\times10^{-12}M_\odot/yr$, and the highest mass—accretion rate has been found on the M1 star HK Tau B with the value of $1.12\times10^{-8}M_\odot/yr$. Two stars, DL Tau and Haro 6-13, show brightness outburst events associated with mass—accretion shocks and columns in the TESS data, and we estimate their mass—accretion rates over a dozen days from the light curves from U—band luminosity excess curve converted from the TESS curve with an approximation factor. In this way, the accretion rate of DL Tau has been derived to be up to $8.81\times10^{-9}M_\odot/yr$ with an average of $2.13\times10^{-9}M_\odot/yr$, which is consistent with the result of $7.53\times10^{-9}M_\odot/yr$ derived from H-alpha luminosity in LAMOST data. It also implies that there may have been an outburst on DL Tau during our LAMOST observation. The average accretion rate of Haro 6-13 is $8.31\times10^{-11}M_\odot/yr$, and the maximum value is $1.14\times10^{-10}M_\odot/yr$ which is slightly lower than that of $5.926\times10^{-10}M_\odot/yr$ derived from our LAMOST data, suggesting the star could be able to produce the outburst stronger than those we see in the TESS data this time.

KEYWORDS T Tauri Stars, low-mass stars, protostellar disk, young stellar objects, spectroscopic, TESS, lightcurve

Division G

#2060

Constraining the Initial-Final Mass Relation of White Dwarf Stars With Gaia eDR3

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Stellar evolutionary models are remarkably advanced and successfully reproduce observed patterns across the stellar evolutionary tracks. However, the chaotic final stages of White Dwarf formation are the exception to this accuracy. The transition from a giant star to the relatively inert CO core is particularly chaotic and highly sensitive to small changes in internal structure. Processes such as stellar winds and dust formation drive extreme mass loss, which remains a challenge to accurately model. To constrain the modelling of these processes, an accurate Initial-Final Mass Relation (IFMR) of stellar remnants can act as an empirical ground truth. This work presents a machine learning pipeline to increase the census of known White Dwarf stars associated with stellar clusters and comoving groups. We cluster 5-dimensional astrometric data from Gaia eDR3 to increase the population by an estimated order of magnitude. The increase in population aims to constrain the IFMR of White Dwarf stars. Our pipeline combines several machine learning models producing an automated and scalable approach for future surveys and data releases. To ensure the ethos of scalability, we also present a distributed strategy for clustering algorithms such as HDBSCAN in multidimensional data.

KEYWORDS (stars:) white dwarfs, stars: evolution, methods: data analysis, methods: statistical

Division G

#1675

The OGLE Collection of One Thousand Heartbeat Stars

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We present an analysis of 991 heartbeat stars (HBSs) from the OGLE Collection of Variable Stars (Wrona et al. 2022, ApJS, 259, 16; Wrona et al. 2022, ApJ, in press, arXiv:2109.14614). The sample consists of 512 objects located toward the Galactic bulge, 439 in the Large Magellanic Cloud, and 40 in the Small Magellanic Cloud. We model the I-band OGLE light curves using an analytical model of flux variations, reflecting tidal deformations between stars. We present distributions of the model parameters that include the eccentricity, orbital inclination, and argument of the periastron, but also the period-amplitude diagrams. On the Hertzsprung-Russell diagram, our HBS sample forms two separate groups of different evolutionary statuses. The first group of about 90 systems, with short orbital periods (P<50 days), consists of an early-type primary star lying on (or close to) the main sequence. The second group of about 900 systems, with long orbital periods (P>100 days), contains a red giant (RG). The position of RG HBSs on the period-luminosity diagram strongly indicates their binary nature. They appear to be a natural extension of confirmed binary systems that include the OGLE ellipsoidal and Long Secondary Period variables. We also present a time-series analysis leading to the detection of tidally-excited oscillations (TEOs). We identify such pulsations in about 5% of stars in the sample with a total number of 78 different modes. This first relatively large homogeneous sample of TEOs allowed us to construct a diagram revealing the correlation between the TEO's orbital harmonic number and the eccentricity of the host binary system. The detection of high-amplitude TEOs in RGs is a step forward in applying tidal asteroseismology to these evolved stars.

KEYWORDS binary stars, heartbeat stars, time domain astronomy, periodic variable stars, stellar pulsations, tidally excited oscillations, celestial objects catalogs

Division G

#1703

The tidally excited oscillations in massive heartbeat stars from MESA-binary and GYRE point of view

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Massive main-sequence stars frequently reside in binary and multiple systems. Since they are also young, the systems they belong to usually did not have enough time to circularise their orbits. In effect, many massive stars are found in highly eccentric systems. Eccentric ellipsoidal variables (also known as heartbeat stars) is a class of eccentric binaries in which proximity effects, and tidal distortion due to time-dependent tidal potential in particular, lead to measurable photometric variability close to the periastron passage. The varying tidal potential may also give rise to tidally excited oscillations (TEOs), which are forced eigenmodes with frequencies close to the integer multiples of the orbital frequency. TEOs may play an important role in the dynamical evolution of massive eccentric systems and it is still a poorly understood field of research. Using the Modules for Experiments in Stellar Astrophysics (MESA) binary module and the GYRE linear nonadiabatic stellar oscillation code, we simulate the evolution of thousands of massive eccentric binary systems and study the conditions that allow excitation of TEOs in these systems (Kołaczek-Szymański & Różański, in preparation). Next, with the help of machine learning, we try to distinguish certain groups of massive binary systems, with respect to their chance of exciting TEOs. Our main goal is to answer the question of whether there are some specific combinations of the initial parameters of massive binary systems that favor the occurrence of TEOs throughout the stellar lifetime. These in turn may lead to the intense dissipation of orbital energy and tightening of the orbit of the components. The consequence of such an evolution may be an earlier moment of the first mass transfer or even the coalescence of both components.

KEYWORDS binary systems, massive stars, tidal interactions, tidally excited oscillations, MESA software, GYRE code, numerical simulations

Division G

#1814

Constrain orbital solutions of subdwarf B binary systems using TESS

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Subdwarf B (sdB) star is an extreme horizontal branch star with high temperature and gravity. The most promising formation scenarios involve close binary star evolution with three different channels: [1] a Common Envelope channel, which can produce short period (P=0.1–10 d) sdB + white dwarf (WD) or main sequence (MS) binaries, [2] a Roche lobe overflow channel, which results in a long period (450 < P < 1400 d) sdB + MS binaries, and [3] a WD merger channel, which can produce single sdB stars. To test these scenarios, population studies and orbital information studies in each channel are essential. The short period binaries (Channel [1]) are easier to search using the eclipses and radial velocities (RV) methods. Therefore, about 150 of those systems are known. However, the observational studies for long period binaries and single stars (channels [2] and [3]) are not well done yet.

Approximately 30% of sdB stars show stable pulsations, so the pulsation timing method (or so-called O-C method) is an effective tool to search for long-period binary systems or single stars. Positive detection of a binary system can be obtained from a periodic change of a pulsation mode phase, which is the consequence of a star's reflex motion. We can also confirm single stars by non-detection of such phase variations. The obstacle to using this method is that continuous observation is essential to trace the pulsation timing change due to the orbital motion. The continuously observed data using Kepler, K2, and TESS are ideal for this method.

We use about 140 pulsating sdB stars observed in TESS cycles 1-4 to search for the constraints of the sdB+MS binary system orbital solutions and the possibility of single sdB stars. The Gaia color-magnitude diagram of those targets shows that there may be about 20 sdB+MS candidates among those. This poster introduces this specific method and displays the search results.

KEYWORDS hot subdwarf, pulsation, timing method, O-C method, binary, binary evolution, extreme horizontal branch

Division G

#1755

Using the Hubble Space Telescope and SOFIA to study the evolving Symbiotic Mira, HM Sge

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We have used WFC3 and COS on-board the Hubble Space Telescope and FORCAST and EXES on-board the SOFIA observatory to investigate the unique and evolving symbiotic Mira, HM Sge. The system is the most recent (1975) nearby symbiotic to have an outburst, brightening six orders of magnitude in the optical. Capitalizing on the wealth of archival data, we can use a multi-wavelength approach to get a clear current snapshot of the relaxing system's dust, kinematics, and nebular environment, and how they have evolved over the last fifty years. Advances in instrument capabilities, resolution, and sensitivity will also allow us to probe this system in ways that we never have before, and contemporaneous observations can allow us to consistently model the data from the UV to IR.

KEYWORDS Asymptotic giant branch stars, Mira variable stars, Symbiotic binary stars, Circumstellar dust

Division G

#1584

Peculiar Feature in the λ5018 Emission Line of Symbiotic Stars, AG Dra, AX Per, CH Cyg, Z And, and MWC 560

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We present optical spectral monitoring results for symbiotic stars AG Dra, AX Per, CH Cyg, Z And, and MWC 560 observed at the Bohyunsan Optical Astronomy Observatory in recent years. We investigate the characteristics and variations of the emission line of λ5018. In some symbiotic stars, the λ5018 line is known as the Fe II line, but it is not certain for AG Dra. The changing pattern of the λ5018 emission line according to the activity and phase will be discussed.

KEYWORDS Symbiotic star, AG Dra, Variation of λ5018 line

Division G

#1542

The Photometric and Spectroscopic Studies of Two Algol-type Eclipsing Binaries with Short Orbital Period; EW Boötis and XZ Canis Minoris

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We performed photometric and spectroscopic studies of two Algol-type eclipsing binaries, EW Boo and XZ CMi, with short orbital periods of less than 1 day. The eclipse timing variation of the two systems showing quasi-periodic changes was interpreted as a light-time effect(s) caused by additional bodies. The ground BVRI observation and TESS light curves, together with double-lined radial velocity curves, for two systems, were simultaneously solved to determine the system parameters with high precision and absolute dimensions of their components better than 5% precision. Our result confirms the previous studies that the primary star of EW Boo is located near the blue edge of δ Sct instability, and the primary star of XZ CMi is located at the intersection of δ Sct and γ Dor instability. The multiple frequencies of δ Sct pulsation were detected in the light curves of EW Boo, while no valid signal of pulsations was found in the light curves of XZ CMi. We also discuss the possible evolutionary paths for two systems.

KEYWORDS eclipsing binary, Algol

Division G

#925

Oscillation mode parameters of evolved stars observed with Kepler/K2: Dependence on property of stellar clusters

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The oscillation of solar-like stars is characterized by the fundamental stellar quantities, such as effective temperature, radius, mass, age, so that stellar parameters can be observationally obtained via asteroseismic analysis. To accurately estimate stellar parameters, scaling relations are to be calibrated in terms of metallicity, evolutionary status of stars, and so on. Here, we have attempted to explore the dependence of those with evolved stars in a range of stellar clusters whose properties are known by isochrone analysis. We have employed not only individual mode-parameters of the stellar oscillations but also the global parameters of the stellar oscillation power excess, i.e., frequency of maximum oscillation power νmax, large frequency separation Δν, power excess width δνenv, and small frequency separation δν02, obtained from 151 Kepler/K2 evolved stars belonging to the open clusters NGC2632, NGC2682, NGC6774, NGC6791, NGC6811, NGC6819, and NGC6866. Results from analysis with the Python package Lightkurve and PBjam are presented and discussed in comparisons with parameters from isochrone fitting and individually observed stellar attributes.

KEYWORDS Asteroseismology, Data analysis, Open clusters

Division G

#811

A photometric and spectroscopic study of the contact binary V505 Lacertae

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The physical properties of V505 Lac were investigated through the simultaneous analysis of our ground-based photometric and spectroscopic observations as well as TESS photometric observations. From our observations, multi-band light and double-lined radial velocity curves were secured. Both our and TESS light curves show a weak O'Connell effect. The time series TESS curves show that the O'Connell effect changes slightly in size and shape with each cycle. The temperatures and projected rotational velocities for each star were obtained with the spectra disentangling and modeling code. The subtracted spectra obtained by the spectral subtraction technique show the excess emission in CaII H&K and Hα lines suggesting a strong chromospheric activity. Furthermore, the phase variation of the excess emission lines coincides with the phase change due to the Doppler effect by the orbital motion of the more massive star, indicating that the excess emission lines are from this component. To figure out the physical parameters, both light and radial velocity curves were simultaneously solved with the Wilson-Devinney binary code considering a spot model. The results show that V505 Lac is a W-subtype shallow contact binary system having a fill-out factor of 18%, a mass ratio of 2.759, and an inclination of 60.5deg. The evolutionary status of V505 Lac is also discussed based on the absolute parameters.

KEYWORDS eclipsing binary stars, contact binary

Division G

#617

HADS/SX Phe seen by TESS

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TESS satellite provides superb-quality light curves for many variable stars. Among them, there are high-amplitude δ Scuti stars (HADS) stars which pulsate mainly in radial modes with periods of the order of 1-3 hours. I will present the results of the analysis of TESS light curves from sectors 1-13. The pulsational behaviour of the sample will be characterized by means of the parameters of the Fourier decomposition and period ratios (Petersen diagram). The occurrence of non-radial modes and high radial overtones in HADS stars will be also discussed.

KEYWORDS hads, sx phe, pulsations, petersen diagram, fourier parameters

Division G

#363

Study of Silicon Monoxide (SiO) around oxygen-rich AGB stars

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Silicon Monoxide (SiO) is an important dust precursor molecule for oxygen-rich Asymptotic Giant Branch (AGB) stars. It is involved in the formation of silicate grains, a process that is not well understood. Our goal is to determine the distribution of SiO throughout the circumstellar envelopes (CSE) of a focused sample of oxygen-rich AGB stars with known mass loss rate and to understand the relation between the SiO abundance and mass-loss rate of the stars. High spatial resolution ALMA data is used to find better constraints on SiO in the inner part of the CSE. Other data (from single-dish telescopes such as APEX and Herschel/HIFI) are also included in the line fitting to balance the result as they are more sensitive in the outer part of the CSE. Radiative transfer modeling is used to obtain the radial abundance distribution of SiO. Instead of a simple Gaussian distribution, which has been assumed in the past, we test several alternative abundance distribution shapes, which allow us to more precisely understand where SiO is present in the gas phase and where it might be condensing into dust. Early results for IK Tau show SiO increasing from the inner to intermediate wind, which is the opposite of what is expected; previous studies have assumed that dust condensation will remove SiO from the gas phase in a similar region.

KEYWORDS stars: AGB and post-AGB, circumstellar matter, submillimeter: stars

e-Talks

Division G

#3230

Planet-induced spirals in the circumbinary disk of GG Tauri A

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We will present indirect evidence for planet formation in a multiple system, GG Tau A, which harbors the most massive circumbinary disk among T Tauri stars. ALMA observations at ~0.3" (50 au) of CO and CS confirm the "hot spot" detected at higher frequencies, but also reveal prominent spiral-like features. The brightest spiral is well reproduced by a density wave excited by a protoplanet (GG Tau Ac) at the "hot spot" location (290 au), just outside the dust ring. The absence of a clear gap (in gas or dust) at the planet's location implies that its mass is significantly lower than that of Jupiter (i.e., about the mass of Neptune or lower). Furthermore, other prominent (trailing) spiral patterns can be represented by adding one (or more) planet(s) at larger orbital radii, with the most obvious candidate located near the 2:1 mean-motion resonance with GG Tau Ac. The (proto-)planet GG Tau Ac appears to externally confine the ring in a stable configuration, explaining its high mass. Our results also suggest that planets similar in mass to Neptune may form in dense circumbinary disks orbiting (wide) binary stars. In the GG Tau case, orbital resonances appear to play an important role in shaping this multiple circumbinary planet system.

KEYWORDS protoplanetary disks, planet formation, GG Tau A

Division G

#3119

An unbiased NOEMA 2.6 to 4 mm survey of the GG Tau ring: First detection of CCS in a protoplanetary disk

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We will present a chemical survey of GG Tau A triple T Tauri system and report the first detection of CCS in a protoplanetary disk. Molecular line surveys are among the main tools to probe the structure and physical conditions in protoplanetary disks (PPDs), the birthplace of planets. We aimed to study the chemical content of the protoplanetary disk surrounding GG Tau A, a well-known triple T Tauri system. We used NOEMA with the new correlator PolyFix to observe rotational lines at ~2.6 to 4 mm from a few dozen molecules. We detected 17 molecules in the GG Tau A outer disk, in which the CCS has been detected for the first time in PPDs. We analysed the data with a radiative transfer code (DiskFit) to derive molecular densities and the abundance relative to 13CO, which we compare to those of the TMC1 cloud and LkCa 15 disk. In comparison with existing chemical model results, the analysis confirms that sulphur chemistry is not yet properly understood. The D/H ratio, derived from DCO+ /HCO+ , DCN/HCN, and DNC/HNC ratios, points towards a low temperature chemistry.

KEYWORDS protoplanetary disks, Astrochemistry, GG Tau A

Division G

#3106

Uncovering the formation process of the Galactic OB associations from a kinematic perspective

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OB associations are large stellar systems composed of young stellar groups spread over several tens of parsecs or even hundreds of parsecs. They are the prime sites of star formation in galaxies. More than one stellar cluster and distributed stellar populations are, in general, found in such stellar systems. It has been believed that such structural features may contain clues to the formation process of OB associations. Based on the structural features, there are three theoretical models explaining the formation of OB associations, e.g., the expansion of stellar clusters after rapid gas expulsion, structure formation in turbulent molecular clouds, and feedback-driven star formation. In a series of our studies, we have tested these theoretical models using the Gaia data and high-resolution spectroscopy. The targets of this study are six OB associations (Aur OB2, Cyg OB2, Car OB1, Cas OB6 W4, Mon OB1, and Mon OB2) in the Galaxy. These associations have different levels of substructures. Stellar clusters are the most prominent component constituting the substructures. Most of them show a pattern of expansion and some clusters are found to rotate. These results give us important constraints on the cluster formation, e.g., the formation of stellar clusters in rotating clouds or the hierarchical assembly of small units. In addition, the expansion of clusters provides clues to the origin of low-stellar density halos around them given the fact that the proper-motion vectors of the halo stars are pointing out of the clusters. On the other hand, stellar groups are found around stellar clusters. Some of them show receding motions away from ionizing sources in the clusters. Also, there are age differences between the stellar groups and the clusters, suggesting the possibility of feedback-driven star formation. However, the other groups do not show such systematic motions from the stellar clusters. It implies that some stellar groups may spontaneously form in their current positions. In conclusion, our comprehensive results suggest that OB associations may form through two or all of the three processes proposed by the theoretical models.

KEYWORDS Star formation, Stellar kinematics, Stellar associations, Stellar dynamics, Open star clusters

Division G

#3018

Magnetic confinement in the wind of low mass stars

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Magnetic confinement of material is observed on both high and low mass stars. On low mass stars, this confinement can be seen as slingshot prominences, in which condensations are supported multiple stellar radii above the surface by strong magnetic fields. Magnetic confinement has also been observed around the star AB Doradus through radio emission, the exact nature of which is not fully clear but has been explained by some sort of large scale magnetic structure. We present a model for generating cooled field lines in equilibrium with the background corona, which can be used to populate a model corona.

The model produces masses on the order of observationally derived values for the star AB Doradus. We find that there are two types of solutions: "solar-like prominences" which are footpoint heavy and "slingshot prominences" which are centrifugally supported with dense summits. These can form within the open field region i.e. embedded in the wind. H-alpha spectra are generated from a few different field structures and all show similar behaviour that is consistent with observations. This implies that the features seen in observations could be supported by a range of conditions, suggesting they would be common across rapidly rotating stars.

KEYWORDS Low mass stars, Magnetic fields, Magnetic confinement, Young stars, Solar-like stars

DIVISION H

Interstellar Matter and Local Universe

Invited & Contributed Talks

Division H

#2888

Studying the ISM in the Era of JWST

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The observed properties of molecules and dust grains can be studied from the UV to radio wavelengths, including the wavelength-dependent extinction, the UV extinction bump, the Diffuse Interstellar Bands (DIBs), extended red emission (ERE) and Blue Luminescence, the Unidentified infrared (UIR) bands, and the anomalous microwave emission. All these features are essentially unidentified, but we are now reaching some consensus on their nature.

Over the past few years, I have been studying some of this inventory at optical and near-IR wavelengths. My thesis research work marked a turning point in the methods and goals associated with the DIBs and ISM spectral features, and turned these molecular features themselves into powerful probes of the conditions in their surroundings. Now I am particularly interested in studying interstellar species from another angle: in the mid-infrared region, with a focus on dust evolution, through the analysis of JWST Guaranteed Time observations of photon-dominated regions (PDRs) taken in the first year of operation. The JWST will allow us to spatially resolve dust emission and scattering, and the emission lines of key molecules.

KEYWORDS interstellar medium, dust, infrared, molecules, JWST, extinction, lines: absorption

Division H

#2241

Metallicity Distribution Functions of Local Group Dwarf Galaxies from Hubble Space Telescope Narrow-band Imaging

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The metallicity distribution function (MDFs) of stars in dwarf galaxies are rich in information about the baryonic processes that shaped their formation and evolution. However, owing to a combination of few bright stars and large distances, their MDFs are often not well-populated from only spectroscopic studies of viable targets. Here, I describe two Hubble Space Telescope Ca H&K narrowband imaging surveys aimed at measuring the MDFs of Local Group dwarf galaxies, including 16 ultra-faint galaxies that have very few bright stars and two isolated quenched galaxies (Cetus and Tucana) that located at large distances (~1 Mpc). I first highlight the power of Ca H&K imaging by comparing our inferred stellar metallicities in Eri II with those inferred from spectroscopy. I will then present results for the other observed dwarf galaxies, most of which have no previously published MDFs, and discuss the insights that MDFs provide into processes that shaped their formation. I will also discuss ongoing efforts to investigate faint M31 satellites using the same imaging technique and discuss how Ca H&K imaging is a powerful tool for measuring resolved stellar metallicities for faint, distant, and crowded stars that will be challenging to access spectroscopically.

KEYWORDS galaxies: dwarf, galaxies: Local Group, stars: abundances, stars: imaging

Division H

#608

Constraining the Total Mass of M31 with Precision Astrometry

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High-precision astrometric data from the Hubble Space Telescope (HST) and Gaia are revolutionizing our ability to study the Local Group. Currently, 6D phase space measurements (3-dimensional position and velocity) are available for a majority of the Milky Way's known satellite galaxies and for four (11%) of M31's satellite galaxies. As satellites trace the dark matter halos of their hosts, often, the dynamical properties of a given satellite are used to constrain the mass of the Milky Way (MW) or M31. However, my recent work has shown that using the 6D phase space information for an ensemble of satellite galaxies simultaneously can significantly reduce the current factor of two uncertainty in the mass range of the MW. In this talk, I will describe how dynamical properties derived from 6D phase space information of four M31 satellites (M33, IC 10, NGC 147, NGC 185) can be used in combination with state-of-the-art cosmological simulations to statistically estimate the mass of M31, reducing current uncertainties to 30-60%. Over the next decade, HST will deliver astrometric data for the remainder of M31's satellite population. Applying these methods to the full population of satellites out to ~300 kpc will yield the most precise and complete M31 mass estimate to date. This will be a crucial result for interpreting the severity of classical small-scale LCDM challenges (i.e. missing satellites, too-big-to-fail), the assembly history of M31, and the fate of the Local Group.

KEYWORDS dynamics, M31, satellite galaxy, dwarfs, astrometry, halo, dark matter

Division H

#475

Implications of the travel velocity of the Milky Way on Local Group mass estimates from the Timing Argument

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The total mass of the Local Group (LG) is a fundamental quantity that enables interpretation of the orbits of its constituent galaxies and is needed to place the LG in a cosmological context. However, measuring the LG mass is not straightforward, as the distribution and quantity of dark matter is unknown. One method of determining the LG mass is the Timing Argument (TA), which models the dynamics of the MW—M31 system as a two-body (Keplerian) orbit, and which depends strongly on the measured kinematics of M31. Previous TA studies of the LG mass have attempted to correct for the impact of the LMC on the inferred mass, but suffer from unknowns in the mass and dynamical modeling of the LMC interaction with the MW. However, recent studies of tracers in the MW stellar halo have found that the MW disk is moving with a lower bound "travel velocity" of 32±4 km/s with respect to its outer halo, a byproduct of its merger history and the recent pericentric passage of the LMC. This novel measurement allows us to place model-independent, empirical constraints on the LG mass that account for the measured reflex motion of the disk for the first time. In this talk, I will present our TA model that incorporates the travel velocity of the MW disk using several different compilations of recent kinematic measurements of M31. I will show that we recover lower LG masses than past TA results, and measure a total mass of ~4.5±0.7×1012 Msun that is consistent between datasets. Additionally, I will explain how measurements of more distant tracers may yield even larger values for the travel velocity, which would further decrease the inferred LG mass, and that improvements in the precision of proper motion measurements of M31 with Gaia will improve the precision of mass constraints by a factor of ~2. As a result, the newly measured travel velocity directly implies a lower LG mass than from a system with a static MW halo, and must be considered in future dynamical studies of the Local Volume.

KEYWORDS galaxy dynamics, Local Group

Division H

#1604

Formation of the Andromeda Giant Southern Stream and the 10 kpc ring in the Andromeda galaxy

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Recent observations around the M31 have revealed many traces of past interactions with satellite galaxies. In particular, the Andromeda Giant Southern Stream (AGSS) in the halo and the 10 kpc ring structure in the disc have been drawing attention. The AGSS is a giant structure extending more than 100 kpc from the centre of M31 and is thought to have been formed in a collision with a satellite galaxy about 0.8 Gyr ago (Fardal et al. 2007; Mori & Rich 2008). On the other hand, Block et al. (2006) found the 10 kpc ring structure in M31 made up of gas and dust and argued that the structure was formed by a head-on collision of a satellite galaxy, M32, around 0.2 Gyr ago. They conclude that the mass of M32 at the time of the collision was about one-tenth of the total mass of M31 (~ 1011 M⊙) . Recently, a model has been proposed by Hammer et al. (2018) in which the AGSS and the 10kpc ring structure are formed simultaneously by a single major merger with a mass of more than 1011 M⊙ for the first passage at large pericentric distance.

Here, we investigate the link between the AGSS and the 10kpc ring structures using N-body/SPH simulations of galaxy collisions between the M31 and a satellite galaxy with a mass of less than 1011M⊙. The result demonstrates that the M31 galactic disc is catastrophically destroyed for the collision of massive satellite galaxies, which is consistent with the prediction of our analytic estimation. This impact of the mechanical heating associated with the collision on the disc and the thickness limitation of the present-day disc indicates that the likelihood of collisions with massive satellite galaxies with a mass exceeding 1011 M⊙ is not favourable for central collision. In other words, the results are inconsistent with the collision model for massive galaxies, as claimed in Block et al. (2006). Our simulation indicates that the total mass of the infalling satellite galaxies is likely less than several 1010 M⊙ to reproduce the observed features.

KEYWORDS galaxy collision, evolution of galaxy, N-body and hydrodynamic simulation, M31

Division H

#2607

Star formation laws and gas turbulence in nearby galaxies

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My PhD thesis investigates two key aspects of the link between star formation and cold gas in galactic discs: star formation laws and the origin of gas turbulence. The common theme throughout my work is the importance of the gas disc thickness and its flaring.

In this talk, I first focus on star formation laws linking the star formation rate (SFR) density and the gas density of galaxies. These relations are crucial in studying galaxy formation and evolution. Generally, the Kennicutt law is adopted to link the SFR and gas surface densities with a break at gas densities below a critical threshold for star formation. However, it is still unclear if a more fundamental relation exists for the volume densities. Converting surface densities to volume densities is problematic, as the thickness of gas discs varies with the galactocentric radius and between different galaxies. By assuming the hydrostatic equilibrium, we derived the gas scale heights for 11 spiral galaxies (including the Milky Way) and 12 HI-rich dwarf irregular galaxies. We found that all these galaxies closely follow the same quadratic power law involving the cold gas (HI+H2) and SFR volume densities. This volumetric star formation (VSF) law has a smaller scatter than the Kennicutt law and no break, suggesting that there is no density threshold for star formation.

Lastly, I focus on the origin of cold gas turbulence in galactic discs. Since turbulence is expected to be quickly dissipated by the gas viscosity, it needs to be maintained by some energy source. This latter has remained unknown so far, as even the prime candidates, supernova explosions, have been considered insufficient. A crucial improvement is obtained in my thesis by realising that the gas disc thickness slows down dissipation, in particular in the outskirts of galaxies, thus reducing the energy required to sustain turbulence. This brings to the conclusion that supernova explosions can feed cold gas turbulence, finally solving the conundrum.

KEYWORDS star formation, ISM structure, spiral galaxies, dwarf galaxies, gas kinematics and dynamics, stellar feedback, Milky Way

Division H

#2727

WISDOM:
Molecular cloud properties and star-formation quenching

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Using observations from the WISDOM survey that spatially resolve (1-30 pc) individual molecular clouds across the Hubble sequence, we reveal a clear dependence of the nature of the molecular interstellar medium of galaxies on Hubble type, and present a simple diagnostic of cloud formation. In particular, we highlight the shortcomings of the usual virial approach to clouds as self-gravitating objects, and stress the importance of the external galactic potential and in-plane shear to regulate the dynamical states of clouds. We also introduce a simple but powerful cloud-cloud collision formalism that accounts for the cloud properties in both nearby and high-redshift systems. Finally, we discuss the impact of these different mechanisms on the star formation efficiency of the clouds and thus the quenching of star formation, particularly in galaxy nuclei and spheroids (morphological quenching).

KEYWORDS Molecular clouds, Star formation, Galaxies

Division H

#2726

A cloud-scale view of the star formation process

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Where do stars form and how is their formation regulated across galactic disks are two critical questions for our understanding of the star formation process. High angular observations of nearby galaxies allow us to sample the star formation process across entire galactic disks reaching now regularly the scales of the star-forming units, namely Giant Molecular Clouds (GMCs) and HII regions. Such data provide new insights on the molecular gas reservoir and its role in the star formation process as well as information on the importance of galactic components such as bulges, stellar bars, spiral arms and active galactic nuclei (AGN) in the conversion of cold (molecular) gas into stars. The PHANGS (Physics at High Angular resolution in Nearby GalaxieS) collaboration is assembling a multi-wavelength database enabling cloud-scale studies for nearby galaxies. I will present highlights from the ongoing research of the collaboration.

KEYWORDS star formation and ISM in nearby galaxies, cloud-scale observations

Division H

#2207

The 30 Doradus Molecular Cloud as Revealed by ALMA

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We present results of a wide-field (approximately 60 x 90 pc) ALMA mosaic of CO(2-1) and 13CO(2-1) emission from the molecular cloud associated with the 30 Doradus star-forming region. 30 Dor is the most active star-forming region in the Local Group, and the key prototype of a high-radiation field, low-metallicity star-forming environment. Three main CO emission complexes, including two forming a bowtie-shaped structure extending northeast and southwest from the central R136 cluster, are resolved into complex filamentary networks. Consistent with previous studies, we find that the central region of the cloud has higher line widths at fixed size relative to the rest of the molecular cloud and to other LMC clouds, indicating an enhanced level of turbulent motions. However, there is no clear trend in gravitational boundedness (as measured by the virial parameter) with distance from R136. We will briefly touch upon work in progress and opportunities for further study of this region.

KEYWORDS LMC, Molecular Clouds

Division H

#1541

Binary Formation in the Massive Cluster-formation Region

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Most massive stars form in binary or higher order systems in a cluster. Binary is known to significantly affect the evolution and fate of massive stars. Investigating the early evolutionary stages of binary or multiple systems is of fundamental importance for comprehension of the formation and evolution of clusters. Fragmentation is a ubiquitous physical process that is a key to enable the formation of multiple system from a dense core and govern the properties of stellar clusters. Understanding the fragmentation processes and the properties of multiple system is critical for revealing a complete picture of massive star cluster formation and evolution. In this talk, I will (1) present a study of binary or multiple systems formation via fragmentation from the ~1 pc clump scale all the way down to ~300 au disk scale in a massive cluster-forming region; (2) discuss the dynamical role of magnetic fields, gravity, and turbulence in the formation binary and multiple systems.

KEYWORDS Massive star formation, Binary, Molecular cloud

Division H

#3452

Mapping the Ancient Milky Way and its Relic Dwarf Galaxies

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The Milky Way hosts populations of metal-poor stars and dwarf galaxies that formed at high redshifts and still continue to exist today. These objects function as time capsules that provide a local bridge toward our understanding of the earliest stars and galaxies. In this thesis talk, I will present several pioneering studies of the Milky Way's ancient stellar populations and dwarf galaxies, including (1) a large-scale mapping of ancient, low-metallicity stars in the Galaxy, (2) insights into the early evolution of carbon in one dwarf galaxy with implications on the early assembly of the Milky Way, and (3) a detection of an extended "halo" of stars around a tiny (~3000 stars) relic galaxy. The latter discovery is the first direct evidence that primitive galaxies formed in massive, extended dark matter halos, and suggests that even the tiniest galaxies may have had an early merger history. Most of these discoveries were enabled by my development and implementation of imaging analyses that have led to nearly an order-of-magnitude improvement in the efficiency of identifying the most ancient, metal-poor stars relative to traditional spectroscopic techniques. Such analyses are readily scalable with upcoming surveys (e.g., LSST) for the next generation of studies targeting the ancient Milky Way.

KEYWORDS

Division H

#752

Evidence of ram pressure stripping of WLM, a dwarf galaxy far away from any large host galaxy

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Dwarf galaxies are affected by all the evolutionary processes normally at work in galaxies of any mass. As fainter and less massive galaxies, however, dwarf galaxies are particularly susceptible to environmental mechanisms that can more easily perturb these systems. Importantly, the presence of nearby large galaxies is expected to have a profound effect on dwarf galaxies. Gravitational (especially tidally induced) effects from a large galaxy can cause mass to be lost from a dwarf, and the passage of the dwarf though the gaseous medium surrounding a large galaxy can additionally cause the dwarf to lose its own gas through "ram pressure stripping". Such effects are the main sources of difference between "satellite" and "field" dwarf galaxy populations. Here, we report on new observations, using MeerKAT, of the gaseous content of Wolf-Lundmark-Melotte (WLM), an archetype of isolated, gas-rich field dwarf galaxies in the Local Universe. Previous studies of its gaseous disk suggest it has perturbed kinematics; here, we identify four trailing, extended gas clouds in the opposite direction to WLM's spatial motion, as well as a spatial offset between the WLM gas and stars. Overall, the morphology and kinematics of this gas shows that WLM is undergoing ram pressure stripping, despite being 930 and 830 kpc from the Milky Way and M31, respectively. This finding indicates the presence of an inter-galactic, gaseous reservoir far from large galaxies whose evolutionary role on galaxies, both large and small, may not be fully appreciated.

KEYWORDS ISM, IGM, dwarf galaxy, HI study, MeerKAT, ram pressure

Division H

#1410

Tracing dominant shock mechanisms of Orion A

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We present the kinematics of the closest massive star forming cloud, Orion A, by analyzing the line profiles of the warm envelope and the cold dense medium. We utilize the archival data of 158μm [CII] (SOFIA-GREAT) and 3mm CO isotopic emissions (CARMA-NRO) to be compared to the synthetic observations of the lines based on various shock environments with Paris-Durham code. Our analyses have an ability to examine the local stellar feedback mechanisms (shell expansion and jet/outflow) as well as the large scale turbulence (cloud-cloud collision) in each pixel of the observed maps to address dominant kinematic mechanisms for star formation activities. We explore the contribution of C, CJ, and J-type shocks on the inspected regions as functions of various environmental properties (e.g. density, shock velocity, and magnetic field strength). The results indicate that the northern part of Orion A filament, including OMC-3 region, have significant kinematic contribution of cloud-cloud collision with complementary local feedbacks, while OMC-1 and ONC regions are stellar feedback dominant. We also discuss the star formation scenarios of Orion A cloud and how the different kinematic mechanisms conduce to such activities.

KEYWORDS ISM, GMC, Star Formation, Molecular Clouds, Orion, Infrared

Division H

#2507

Innovating the Hunter Techniques: RAMSES II - RAMan Search for Extragalactic Symbiotic Stars

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Symbiotic systems (SySt) have been searched in the Milky Way and nearby galaxies due to their relevance to better understand the fate of binary systems involving a white dwarf accreting matter from a cool giant. On top of the interesting astrophysical phenomena originated from this symbiosis – non-spherical outflows, highly-collimated jets, supersoft X-rays sources – SySt are also promising candidates as Type Ia supernovae (SNe Ia) progenitors.

Searching for SySt is a hard task that so far resulted in about 275 (74) Galactic (extragalactic) identifications. This very limited statistics motivates surveys aimed at unveiling the missing SySt population. RAMSES II – RAMan Search for Extragalactic Symbiotic Stars – is innovating in the method of searching for SySt, which is based on the GMOS@Gemini narrow-band imaging geared towards the emission of Raman O VI (~ 6830 Å). At variance with the usual ways to discover SySt – optical plus near-IR photometry followed by spectroscopic follow-up – the RAMSES II technique is solely photometric, since the Raman O VI line is a unique proxy of symbiotic systems.

The strategy, challengers, as well as the science results so far obtained through this innovative hunting technique for symbiotic stars will be discussed in this talk.

KEYWORDS Evolved Stars, Symbiotic Stars, Narrow-band Imaging

Division H

#1054

Synthesis and distribution of complex organics by planetary nebulae

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Planetary nebulae are now known as major sources of complex organics in the Galaxy. Beginning in the proto-planetary nebulae phase, nanoparticles of mixed aromatic-aliphatic structures (MAON) begin to form. From the strengths of the spectral features, a large fraction of carbon in planetary nebulae is in the form of complex organics. Due to the sturdy nature of these particles, they can survive their journeys through the interstellar medium and be deposited in sites that condense into future planetary systems. The implications of stellar organics in the primordial Solar System will be discussed.

References

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KEYWORDS organics, solar system, chemical enrichment, planetary nebulae

Division H

#2491

Precision age dating of globular clusters

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Building on our previous analysis of the HST-ACS catalog of globular clusters (GCs), we refined our methodology to mitigate the effect of multiple stellar populations (using Gaussian mixture fit), upgraded our treatment of the stellar physics (specifically the absorption correction) and made use of statistical tools to improve the accuracy of our results. Indeed, we implemented a three-part likelihood model able to account for two possible stellar populations and field stars. We present age estimates for the 69 galactic GCs using a Bayesian technique to fit the full color-magnitude-diagram (CMD). Using the full CMD, we obtained Bayesian posteriors not only for the age but also for distance, metallicity, and dust attenuation. We show that the distances obtained in this way are fully compatible with those obtained from the GAIA-EDR3 catalog. We also paid special attention to the evaluation of systematic uncertainties.

KEYWORDS HST, globular clusters, age determination, stellar populations, GAIA

Division H

#1123

A Blueprint for the Milky Way's Stellar Populations

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We present a synoptic view of stellar populations in the Milky Way Galaxy, based on photometrically derived metallicity estimates from large survey databases and accurate proper motion measurements from Gaia. Along the Galactic prime meridian, we identify groups of stars associated with Gaia Sausage/Enceladus (GSE), the metal-weak thick disk (MWTD), and the Splash (also known as the "in situ" halo) in the observed phase space, and estimate their fractional contributions to the local halo. We find mild (anti-)correlations of GSE stars in the spatial, kinematical, and chemical space, which suggest a negative metallicity gradient of the GSE progenitor and its prograde orbit at infall. Our mapping also indicates that the majority of stars associated with the Splash structure are on prograde orbits, and are causally disconnected from GSE. We discuss possible origins of these structures in the context of galaxy formation.

KEYWORDS Milky Way, Stellar populations, Metallicity distribution, Surveys, Galactic archaeology, Kinematics, Halo

Division H

#572

A Spiral Magnetic Field in a Hub-Filament Structure, Monoceros R2

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We present the results of polarization observations obtained from SCUBA-2/POL-2 on the JCMT at 850 as part of the JCMT BISTRO survey towards Monoceros R2 (Mon R2). Mon R2 shows a clear hub-filamentary structure. We find filaments using FilFinder algorithm and estimate their physical properties. The filaments show a spiral structure and have a coherent centroid velocity distribution of C18O spectral lines along each filament. The polarization segments also follow a spiral structure, so we assume a rotating magnetized disk model as an underlying background magnetic field. The distribution of polarization angle dispersion is estimated using the angle difference between the model and observations. We also obtain the distribution of volume density and velocity dispersion obtained using the column density map obtained by Herschel data and the C18O data taken with the HARP on the JCMT. Substituting three distributions into the Davis-Chandrasekhar-Fermi method, we make maps of magnetic field strengths and mass-to-flux ratios. Magnetic field strengths vary from 0.02 to 1.45 mG and their mean value is 0.41 ± 0.20 mG. The mean value of mass-to-flux ratios is 1.06 ± 0.2, but overall regions in Mon R2 are magnetically sub-critical.

KEYWORDS Star formation, Magnetic fields, Polarization

Division H

#2930

New insights into low-ionization structures in planetary nebulae through statistical analysis

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Planetary nebulae (PNe) are particularly relevant for the Local Universe because they contribute significantly to the chemical enrichment of galaxies. PNe populate quiescent as well as star-forming galaxies and are relatively easy to detect due to their strong emission-lines. However, there are unsolved questions in the field, like the nature of processes that lead to non-spherical PNe; the discrepancies between the recombination and the collisionally-excited emission-line abundances; and the origin of their small-scale, low-ionization structures (LISs). This talk is focused on the latter, structures which are mostly detected using narrow-band images and which possess a variety of shapes such as knots and jets. These micro-structures, unlike the macro ones (shells, rims and haloes), emit mainly in low-ionization species such as [NII], [SII], [OII] or even [OI]. They have been studied for more than 2 decades and their origin or the excitation mechanisms are still under dispute in the present days. One approach to address these problems is to contrast the differences between LISs and the macro-structures of the host nebulae in a statistical way. In this talk I will present the results found after using the so far most complete sample of LISs gathered from the literature. This analysis led us to reinforce the previous conclusions about the electron density in these structures, as well as to reach new findings about electronic temperature obtained from the oxygen diagnostic lines. We also tackle the topic of LISs excitation mechanisms, using different diagnostic diagrams, and conclude that both shock excitation and photoionization are present as the main mechanisms of these intriguing structures.

KEYWORDS ISM: kinematics and dynamics, ISM: jets and outflows, planetary nebulae

Division H

#1812

The Orbital and Chemical Properties of One Dozen Stellar Streams from the Southern Stellar Stream Spectroscopic Survey

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In this talk, I will present the kinematic, orbital, and chemical properties of 12 Milky Way stellar streams with no evident progenitors, using line-of-sight velocities and metallicities from the Southern Stellar Stream Spectroscopic Survey, proper motions from Gaia EDR3, and distances derived from distance tracers or the literature. This data set provides the largest homogeneously analyzed set of streams with full 6D kinematics and metallicities at heliocentric distances between ~10–50 kpc. The velocity and metallicity dispersions show that half of the stream progenitors were disrupted dwarf galaxies (DGs), while the other half originated from disrupted globular clusters (GCs). Some streams appear to have been accreted with the recently discovered Gaia-Enceladus-Sausage system, and others suggest that GCs were formed in and accreted together with the progenitors of DG streams whose stellar masses are similar to Draco to Carina dwarf galaxies. This unique dataset will help improve our understanding of the building blocks of the Milky Way's stellar halo, the progenitors and formation of stellar streams, the mass and shape of the Milky Way's halo, and ultimately the nature of dark matter.

KEYWORDS stellar streams, Milky Way, dark matter, dwarf galaxies, globular clusters, halo, Gaia

Division H

#3293

Constraints to the dark matter nature from the internal structure and orbital pericenters of Milky Way Satellites

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Recent Gaia measurements of the pericenters of Milky Way dwarf galaxies as well as the increasing discovery of more nearby faint satellites in the Local Group can be used to put stronger constraints to scenarios that solve the well-known small-scale problems in the standard model by assuming a different dark matter nature beyond the standard WIMP candidate. In my talk, I will combine these observations to derive new constraints to the nature of dark matter, focusing on the Ultra-light and Self-interacting dark matter models. With the upcoming surveys and the next generation of large telescopes hunting for the faintest and most dark matter dominated satellites in our Local universe, I will show how improving measurements of the internal stellar structure in dwarf galaxies will allow us to distinguish among viable dark matter candidates.

KEYWORDS dwarf galaxies, Milky Way, dark matter, kinematics, galaxy structure, satellites

Division H

#1594

Complex organic molecules detected in twelve high-mass star-forming regions with Atacama Large Millimeter/submillimeter Array (ALMA)

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Recent astrochemical models and experiments have explained that complex organic molecules (COMs; molecules composed of six or more atoms) are produced on the dust grain mantles in cold and dense gas in prestellar cores. However, the detailed chemical processes and the roles of physical conditions on chemistry are still far from understood. To address these questions, we investigated twelve high-mass star-forming regions using the ALMA band 6 observations. They are associated with 44/95GHz class I and 6.7 GHz class II CH3OH masers, indicative of undergoing active accretion. We found 28 cores with COMs emission among 66 detected components and specified 10 cores associated with 6.7 GHz Class II CH3OH masers. Up to 19 COMs are identified including oxygen- and nitrogen-bearing molecules and their isotopologues in the cores. The derived abundances show a good agreement with those from other low- and high-mass star-forming regions, implying that the COMs chemistry is predominantly set by the ice chemistry in the prestellar core stage. One clear trend is that the COMs detection rate steeply grows with the gas column density, which can be attributed to the efficient formation of COMs in dense cores. In addition, cores associated with a 6.7 GHz class II CH3OH maser tend to emit a larger number of COMs. Finally, our results suggest that the enhanced abundances of several molecules in our hot cores could be originated from the active accretion of each source as well as different physical conditions of cores.

KEYWORDS Star Formation, Astrochemistry, Organic molecules

Division H

#2240

Modeling Polarized Thermal Emission from Dust Grains with Iron Inclusions Aligned by Radiative Torques in Low-Mass Protostellar Cores

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Polarized thermal emission from dust grains aligned with magnetic fields (B) is an essential tool for studying magnetic fields in astrophysics. However, dust grains in dense environments such as protostellar cores can have inefficient internal alignment (IA) and may not be aligned with B. The magnetic alignment of dust grains can be enhanced by having iron inclusions as predicted by the Magnetic-Radiative Torque (MRAT) theory. To understand how iron inclusions affect polarized thermal dust emission in star-forming regions, we extend the public POLARIS code to include the magnetic susceptibility of grains and model multi-wavelength polarization from aligned grains toward a protostar. We found that paramagnetic grains have inefficient IA and cannot be aligned with B in the dense core, inducing low polarization degree of $P \sim 1\%$ in the envelope and negligible polarization in the center region. Grains with inefficient IA can have their longest axis aligned with B and reemit polarized thermal radiation with E // B. In contrast, superparamagnetic grains with higher magnetic susceptibility can have efficient IA and align with B in the core more efficiently, producing $P \sim 10\%$ in the envelope and $P > 1\%$ in the core. The extended range of grain sizes with efficient IA due to iron inclusions induces the rotation of polarization vector from E // B at millimeter to $E \perp B$ at sub-millimeter wavelengths. The flipping of E due to the change of IA happens in optically thin wavelengths and is more pronounced for higher fractions of iron inclusions. Our study reveals the importance of iron inclusions on polarized thermal dust emission and opens the new window to study magnetic properties of grains in star-forming regions using dust polarization.

KEYWORDS magnetic field, grain alignment, protostellar core, star formation, polarimetry

Division H

#1857

Ratio Tables of Chemical Species at Equilibrium for Primordial Chemistry

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Numerical simulations for the interstellar medium (ISM) need to include the chemical reaction network to trace the time evolution more accurately. Because chemical reactions produce molecules in ISM, they not only change the physical and chemical properties of the ISM but also affect its evolution. However, it is difficult in practice to include the full network of the chemical reactions in the simulations because there are too many molecules to compute. Hence it is often proposed to use a reduced chemical network that includes the most relevant chemical reactions for given circumstances although making such an accurate reduced network is still practically challenging. This work introduces an alternative method based on the equilibrium states, which can be applicable to many astrophysical phenomena where the chemical time scale is much smaller than the hydrodynamical time scale. As a proof of concept, we apply our idea to primordial chemistry and make ratio tables of chemical species as a function of temperature. We also consider the effect of the background radiation by including photochemical reactions. These tables can be used to compute the amount of each species in the post-process of hydrodynamic simulations.

KEYWORDS Astrochemistry, Astronomical simulations, Chemical abundance, Interstellar medium, Photoionization

Division H

#1577

Constraints on methanol deuteration in prestellar cores

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Methanol, the simplest complex organic molecule, and its mono-deuterated isotopologues, CH2DOH and CH3OD, are routinely observed around protostars across the full protostellar mass range(1,2). If the deuteration of both of its functional groups is equally efficient, the CH2DOH/CH3OD ratio should be equal to three(3). Observations paint a different picture. While the ratio exceeds ten in the case of some low-mass protostars, it can drop to unity for high-mass protostars. This has sparked the discussion if this ratio can be used as a proxy for the physical conditions during the process of star formation.

Due to the lack of a firm CH3OD detection, this ratio has not been constrained for the prestellar stage yet. A lower limit derived in the well-studied prestellar core L1544 is found to be ten(4).

Here, a chemical model that investigates different formation pathways towards deuterated methanol under prestellar conditions(5) will be presented. It combines experimentally derived formation schemes(6), and takes results from quantum chemical calculations into account(7) to investigate a range of core ages, dust temperatures, and gas densities typical for the prestellar stage. Independent of the applied model, the theoretically expected value of three is not obtained, confirming that the deuteration of the two functional groups of methanol is not equally efficient. Moreover, CH3OD formation is inefficient in the majority of the models, which questions the idea that the CH2DOH/CH3OD ratio is a suitable tracer for the dust temperature at the prestellar stage.

In addition, newly obtained observations towards the methanol peak in L1544 with the IRAM 30m and the GBT will be used to get a better observational constraint on the CH2DOH/CH3OD ratio in a prestellar core, and spatially resolve its variation for the first time.

(1) Bøgelund et al. 2018, A&A, 615A, 88B

(2) Taquet et al. 2019, A&A, 632, 19

(3) Charnley et al. 1997, ApJ, 482, 203

(4) Bizzocchi et al. 2014, A&A, 569A, 27B

(5) Kulterer et al., under rev., ACS Earth and Space Chemistry

(6) Hidaka et al. 2009, ApJ, 702, 291

(7) Song & Kästner 2017, ApJ, 850, 118S

KEYWORDS astrochemistry, ISM, deuteration, methanol, prestellar core

Division H

#2572

Density Derivation by Nebular and Auroral/Nebular Lines Ratios

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The transitions between two higher terms of the p2, p3, and p4 configurations generate auroral lines, whereas the transitions between the middle and the lowest terms generate nebular lines. The transitions between the highest and the lowest terms give auroral/nebular (transauroral) spectral line ratios. It has been known that the densities from nebular-type transitions of [N II], [O II], and [S II] are significantly different (i.e., lower) from those of the auroral/nebular-type transitions (Hyung and Aller 1995). Keenan et al. (1996) showed that the [SII] 6716/[SII] 6731 ratio from the metastable 2Do state to the 4So ground state involves another metastable transition, 2Po to 4So ([SII] 4069/ [SII] 4076); the 4So to 2Po transition can contain a contribution from the 4So to 2Do transition. We showed that the above-modified diagnostics for [SII] 6716/[SII] 6731 ratios could apply to planetary nebulae in a physical condition of electron temperature of 5000 - 20,000 K and densities up to Ne ~ 105 cm-3. We discuss a possible similar effect observed for other [N II] and [O II] lines, suggesting much higher densities than indicated by the nebular line ratio alone.

KEYWORDS interstellar medium, planetary nebula, emission line, nebula diagnostics, stellar evolution, atomic data

e-Posters

Division H

#3321

The JCMT BISTRO Survey : The Magnetic Fields of the IC 348 Star Forming Region

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We present 850 μm polarization observations of the IC 348 star forming region in the Perseus molecular cloud as part of the B-fields In STar-forming Region Observations (BISTRO) survey taken with the POL-2 polarimeter on the James Clerk Maxwell Telescope (JCMT). The magnetic field orientations of IC 348 are inferred from 850 μm polarization data, and we find that the overall field is aligned to be perpendicular to the filamentary structure of the region. Polarization fraction decreasing with intensity is also found, whose trend is estimated by power-law and Rice distribution fittings. We also measure the magnetic field strengths of two cores (HH 211 MMS and IC 348 MMS) and a filament area in the region separately by applying the Davis-Chandrasekhar-Fermi (DCF) and Skalidis-Tassis (ST) methods. Both the cores are magnetically supercritical, while the filament is not. Lastly, we study energy balances of the core regions and find that both magnetic field and turbulence are comparable in HH 211 MMS, while turbulence dominates the magnetic field in IC 348 MMS, which is still weaker than gravity.

KEYWORDS Interstellar Medium, Magnetic fields, Polarization

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Division H

#3340

ALMA Discovery of the Chemical Complexity in the Outer Part of the Milky Way

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We here present the first detection of a protostar and the surrounding cocoon of complex organic molecules (i.e., hot molecular core) at the edge of our Galaxy, which is known as the extreme outer Galaxy (Shimonishi et al. 2021, ApJ, 922, 206).

The study of interstellar medium in low-metallicity environments is crucial to the understanding of physical and chemical processes in the past Universe, where the abundance of heavy elements was significantly lower compared to the present-day solar neighborhood. It is believed that the far outer part of our Galaxy still harbors a primordial environment that existed in the early epoch of galaxy formation, because of its low metallicity and small perturbation from Galactic spiral arms.

In this work, we carried out ALMA observations towards a star-forming region, WB 89-789, which is located at a galactocentric distance of 19 kpc. Our high-sensitivity and high-spatial resolution submillimeter observations detected a variety of carbon-, oxygen-, nitrogen-, sulfur-, and silicon-bearing species, including complex organic molecules containing up to nine atoms (e.g., CH3OH, C2H5OH, HCOOCH3, CH3OCH3, C2H5CN, NH2CHO, etc.), toward a warm (>100 K) and compact (<0.03 pc) region associated with a protostar. Deuterated species such as HDO, HDCO, D2CO, and CH2DOH are also detected. A comparison of fractional abundances of complex organic molecules relative to methanol between this outer Galactic protostar and an inner Galactic counterpart shows a remarkable similarity.

The presence of a great chemical complexity in a primordial environment of the extreme outer Galaxy, and its chemical similarity with inner Galactic sources, suggest that the interstellar conditions to form the chemical complexity might have persisted since the early history of the Universe. However, the universality of such a chemical complexity in the outer Galaxy still remains to be investigated.

KEYWORDS Astrochemistry, Interstellar Molecules, Protostars, Metallicity, Submillimeter astronomy

Division H

#3328

Role of Filamentary Structures in the Formation of Two Dense Cores, L1544 and L694-2

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We present mapping results of two prestellar cores, L1544 and L694-2, embedded in filamentary clouds in multiple molecular lines such as 12CO, 13CO, C18O, HCO+, and H13CO+ with the JCMT submillimeter telescope to examine the roles of the filamentary structures in the formation of dense cores in the clouds. We also present new distance estimates for L1544 (175-3+4 pc) and L694-2 (203-7+6 pc) based on stellar photometry and Gaia DR2 parallaxes. By examining the velocity structures and the non-thermal velocity dispersion of filaments along the filament's skeletons identified with continuum emission, we found that the non-thermal velocity dispersions of two prestellar cores and their surrounding clouds are smaller than or comparable to the sound speed. This may indicate that during core formation, the turbulence has been already dissipated for both clouds and cores. We also found that there exists a λ/4 shift between the periodic oscillations in the velocity and the column density distributions implying the possible presence of gravitational core-forming flow motion along the axis of the filament. The mass accretion rates due to these flow motions are estimated to be 2~3 Msol Myr-1, being comparable to the mass accretion rate for Serpens cloud, but much smaller than those for the Hub filaments, cluster or high mass forming filaments by 1 or 2 order of magnitudes. The results of this study show that the filamentary structures in the clouds play an important role in the whole process of formation of dense cores and their evolution.

KEYWORDS Core formation, Star forming regions, Molecular clouds, Interstellar filaments, Dense cores, Filament fragmentation

Division H

#3303

Properties of Globular Clusters in Galaxy Clusters: sensitivity from formation and evolution of globular clusters

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We investigate the properties of globular clusters in a galaxy cluster, using the particle tagging method with a semi-analytical approach in a cosmological context. We assume globular clusters form from halo mergers and their metallicity is assigned based on host halo stellar mass and formation redshift. Dynamical evolution and disruption of globular clusters are considered using semi-analytical approaches, controlled by several free parameters. In this paper, we investigate how our results are changed by the choice of free parameters. We compare our fiducial results with representative observations, including the mass ratio between the globular cluster system and its host halo, globular cluster occupancy, the number fraction of blue and red globular clusters, and metallicity gradient with the globular cluster mass. Because we can know the positions of globular clusters with time, comparison with additional observations is possible, e.g. the median radii of the globular cluster system in individual halos and the mean projected density profiles of intracluster globular clusters, and metallicity and age gradients of globular clusters with a clustercentric radius.

We also find that the specific mass of the globular cluster system in each halo is different with a clustercentric radius.

KEYWORDS Galaxy Clusteres, Globular Clusters, Numerical Simulation

Division H

#3259

Gemini High-resolution Infrared Spectroscopy of Red Point-like Objects in the Central Molecular Zone

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We present preliminary results from high-resolution near-infrared spectroscopic observations of 5 red point-like objects in the Central Molecular Zone (CMZ) using GNIRS at Gemini North. Our sample shows distinctly redder infrared colors than the majority of the sources toward the CMZ. In addition, given the presence of 2.3 μm CO band-head absorptions and strong 3.0 μm absorption from H2O ice, most of our sample objects are likely giants behind extended envelopes of a young stellar object (YSO) or a dense cloud core in each line of sight. In support of this view, we also detect 3.54 μm absorption from CH3OH ice in 3 objects. We refine a mixing ratio of CH3OH-CO2 ice based on this study and our previous measurements and find N(CH3OH)/N(CO2) = 2.6 ± 0.7.

KEYWORDS Spectroscopy, Galactic Center, Central Molecular Zone, Star Formation, Methanol Ice, Young Stellar Objects

Division H

#3245

9.7µm Methanol Ice Absorption toward Red Point-like Objects in the Central Molecular Zone

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Methanol ices form in dense environment, and therefore can be used to trace regions with active star formation. Here, we study mid-infrared spectra of red point-like objects in the Central Molecular Zone (CMZ) and report a detection of 9.7 µm absorption band from C-O bending mode of solid CH3OH in 4 objects. Our analysis provides an additional support that CO2 shoulder ice absorption at 15.4 µm is induced by CO2 ice mixed with CH3OH.Our data further indicate a mixing ratio of N(CH3OH)/N(CO2) = 2.539±0.62.

KEYWORDS spectroscopy, methanol ice, central molecular zone, the Milky Way

Division H

#3210

Polarization observations toward the Class I protostar TMC-1A using the SMA and ALMA

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Our previous ALMA observation identified an infall velocity at three tenths of the free-fall velocity in the envelope of the Class I protostellar system TMC-1A (Aso et al. 2015). We suggested that a magnetic effect with a field strength of ~2 mG may explain the slow infall velocity. To verify this estimate, we observed TMC-1A in polarized continuum emission at 1.3 mm using the SMA and ALMA at ~400 and ~40 au resolutions, respectively. The SMA result shows polarization directions between parallel and perpendicular to the outflow direction. The magnetic field pattern inferred from this result can suppress gas motion in the midplane. We applied the Davis-Chandrasekhar-Fermi method to the detected polarization and verified the magnetic-field strength on the order of mG. The ALMA result shows polarized emission in the central ~40 au and ~100 au away from the center to the north and south. In the central region, the polarization direction is mainly in the minor-axis of the associated disk, while it is in the azimuthal direction at the outer part of this region. This is a typical pattern in the case of polarization due to self-scattering. The northern/southern polarized emission is detected along the minor-axis, and the polarization direction is also in the minor-axis. This pattern is likely produced by grains aligned in a toroidal magnetic field. In addition to polarization, we also identified a spiral-like component in Stokes I. We investigated the velocity structure along the spiral using in the C18O J=2-1 line emission, suggesting an infalling rotating motion along the spiral. The spiral direction coincides with the magnetic-field direction inferred from the polarization result on the northern side. This may implies that the infalling rotating motion is magnetically channeled.

KEYWORDS Protostars, Polarization, ALMA, SMA, Magnetic field, Self-scattering, Kinematics

Division H

#3097

The Second Release of the 12CO (J=3-2) High-Resolution Survey (COHRS)

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We present the second release (R2) of data from the 12CO (J = 3 ⟶ 2) High-Resolution Survey (COHRS), which has mapped the inner Galactic plane over the range of $10° \lesssim l \lesssim 62°$ and $|b| \leq 0.°5$. The COHRS has been carried out using the Heterodyne Array Receiver Program on the 15 m James Clerk Maxwell Telescope in Hawaii. The released data are smoothed to have a spatial resolution of 16."6 and a velocity resolution of 0.635 km/s, achieving a mean root-mean-square of ~ 0.6 K. The COHRS data help investigate detailed three-dimensional structures of individual molecular clouds and large-scale structures such as spiral arms in the Galactic plane. Furthermore, data from other available public surveys of different CO isotopologues with a similar angular resolution to this survey, such as FUGIN, SEDIGISM, and CHIMPS/CHIMPS2, allow studying the physical properties of molecular clouds and comparing their states with each other. We describes further observations on R2 and improved data reduction since the original COHRS release. We discuss the characteristics of the COHRS data and present integrated-emission images and a position-velocity (PV) map of the region covered. The PV map shows a good match with the spiral-arm traces with existing CO and HI surveys. We also compare the longitudinal distributions of the lowest CO transition and star-forming population.

KEYWORDS ISM:clouds, ISM:structure, molecular data, submillimeter:ISM

Division H

#3096

Precision age dating of globular clusters

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Building on our previous analysis of the HST-ACS catalog of globular clusters (GCs), we refined our methodology to mitigate the effect of multiple stellar populations (using Gaussian mixture fit), upgraded our treatment of the stellar physics (specifically the absorption correction) and made use of statistical tools to improve the accuracy of our results. Indeed, we implemented a three-part likelihood model able to account for two possible stellar populations and field stars. We present age estimates for the 69 galactic GCs using a Bayesian technique to fit the full color-magnitude-diagram (CMD). Using the full CMD, we obtained Bayesian posteriors not only for the age but also for distance, metallicity, and dust attenuation. We show that the distances obtained in this way are fully compatible with those obtained from the GAIA-EDR3 catalog. We also paid special attention to the evaluation of systematic uncertainties.

KEYWORDS HST, globular clusters, age determination, stellar populations, GAIA

Division H

#3032

Warp and flare of the Galactic disc revealed with Gaia

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The outer Galactic disc contains intriguing features such as the warp and flare, whose origin is still debated. We make use of the Gaia data, which provide an excellent opportunity to probe Galactic disc at large distances and study these features.

We calculate the density distribution of the Galactic disc using star counts obtained from Gaia DR2 and Gaia EDR3 up to a Galactocentric distance of 20 kpc, and we use them to constrain their warp and flare. To recover the star counts, we carry out deconvolution by applying Lucy's inversion method - an iterative Bayesian method without assuming any prior. We also study the population of supergiants (representative of a young population) separately and analyse how the properties of the warp and flare phenomena depend on the studied population.

By fitting the stellar density with various models, we find an asymmetric warp with a small amplitude, the northern warp being slightly lower than the southern warp. The supergiants have an asymmetric warp as well, reaching an amplitude almost twice as high as the amplitude of the whole population of the disc. The difference between the warps of the two populations is significant, revealing a relationship between the age of the studied population and the warp amplitude. This result suggests that the warp should be induced by a non-gravitational mechanism. For the flare, we observe the opposite trend - we find a significant flare of the whole population, especially in the thick disc, however, the supergiants' population manifests only a subtle flare.

KEYWORDS Galaxy:disc, Galaxy: structure

Division H

#2955

Multi-layer Kinematic Properties of Orion A

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We present the kinematic properties of Orion A as the tracers of major star formation mechanisms. Orion A is the closest massive star forming cloud thus has been the best laboratory to study star and star cluster formation with wide range of stellar masses. Recent studies indicate that the cloud-cloud collision is potentially an important trigger of the star cluster formation in Orion A along with the strong stellar feedbacks. We utilize CARMA-NRO 13CO(1-0) and SOFIA-GREAT 158μm [CII] data to be compared to theoretical shock models of Paris-Durham shock code. We analyze differences created by changing parameters such as density, shock velocities, and magnetic field strength for C-, CJ- and J-type shocks to cover the effects of slow (via cloud-cloud collision) and fast (stellar feedback such as jets/outflows) shocks. We discuss the results of the comparison between models with different parameters and observations, and then compare results and ensuing differences with previous studies and findings.

KEYWORDS Orion A, Star Formation, Infrared, Molecular Clouds

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Division H

#2039

Evolution of dark matter subhalos with an effect of tidal stripping from the growing Milky-Way-like host halo

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In the CDM universe, small dark matter halos play an essential role as a building block in the hierarchical structure formation scenario. We investigate the dynamical evolution of dark matter subhalos in the mass range of dwarf galaxies (106 ~ 1010 $M_\odot$) using data from Phi-4096 (Ishiyama et al. 2021), the latest ultra-high-resolution cosmological N-body simulation. This analysis used data from a total of 300,000 subhalos bound to the gravitational potential of 27 Milky Way size host haloes. The results show that tidal forces from the host halos strongly influence more than 90% of the subhalos during their mass evolution. The evolutionary track of the subhalos has two phases: an accretion phase in which the mass increases due to collapse and merger, and a tidal stripping phase in which the mass decreases due to the tidal force from their host halo. This result strongly confirms that the tidal stripping mechanism occurs universally during the evolution of the subhalos. In addition, the latest observations presented by Gaia have provided highly accurate calculations of the orbital motion of satellite galaxies associated with the Milky Way. We directly compared the statistical properties of the orbital motion of the subhalo predicted by the CDM model and the actual orbital motion of the satellite galaxy. The results show no discrepancy between the predictions of the CDM model and the actual observations of satellite galaxies.

KEYWORDS dark matter halos, galaxy evolution

Division H

#1931

Near-Infrared Study of Supernova Remnants in the Large Magellanic Cloud

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Supernova (SN) explosions affect the physical and chemical evolution of the interstellar medium (ISM). One of their major roles is the dust processing and destruction in the ISM by radiative shocks in supernova remnants (SNRs), returning grain material to the gas phase.

A survey of 13 SNRs in the Large Magellanic Cloud (LMC) was conducted to study the dust destruction by SNR shocks. The LMC's close proximity and location (nearly face-on geometry and low galactic foreground absorption) make its SNRs easy to explore in great detail, compared to galactic or other extragalactic SNRs. We have analyzed the [P II] (1.189 μm) and [Fe II] (1.257 μm) narrow-band images obtained with the InfraRed Survey Facility (IRSF) at Sutherland, South African Astronomical Observatory (SAAO). This research represents the first time that [P II] emission has been used in imaging observations.

We estimated the P/Fe abundance ratio by using the [P II]/[Fe II] line ratio. This provides a good indication of the dust content and/or processing in the ISM, since P is not depleted whereas Fe is mostly locked in dust grains. We found that some SNRs have P/Fe abundance ratios substantially less than that of the general ISM (e.g., Orion Bar ~ 0.13), indicating that a significant fraction of dust grains are destroyed by shocks. In contrast, there are some SNRs showing P/Fe abundance ratios which are comparable or even greater than that of the general ISM. To explain these high abundance ratios, we consider some scenarios, such as Fe atoms mostly locked onto dust grains, or possible material from SN ejecta. Since they are not isolated from their surroundings, nearby H II regions may be another possibility for the high abundance ratios.

KEYWORDS dust, infrared: ISM, ISM: supernova remnants, Magellanic Cloud

Division H
#1628

YSO Variabilities in Various Timescales

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Variability in Young Stellar Objects (YSOs) can be caused by variation of accretion rates, geometric changes in the circumstellar disks, the stochastic hydromagnetic interactions between stellar surfaces and inner disk edges, reconnections within the stellar magnetosphere, and hot/cold spots on stellar surfaces. To trace the variability, many observational studies have been done at optical wavelengths, but the embedded protostars are obscured at the short wavelengths. On the other hand, monitoring protostars at mid-Infrared (mid-IR) is powerful for tracing the variability over a wide range of evolutionary stages from the embedded protostars to the pre-main sequence stars. We investigate the long-term and short-term variabilities using the two mid-IR survey data, Near-Earth Object WISE (NEOWISE) and Young Stellar Object Variability (YSOVAR). The extension of the Wide-field Infrared Survey Explorer (WISE) mission, NEOWISE provides ~7 years all-sky photometric monitoring at mid-IR (3-5μm) up to now, with 6 months cadence. YSOVAR is a mid-IR survey observation monitoring the variability of YSOs for 40 days (short-term) with the Spitzer Space Telescope. To those two datasets, we apply the method developed by Park et al. (2021) to classify variabilities into six types based on their light curves (Linear, Curved, Periodic, Burst, Drop, Irregular). We present the results of the classification and discuss the differences between long-term (over ~7 years) and short-term (within 40 days) variabilities.

KEYWORDS YSO, Variability, NEOWISE, YSOVAR

Division H

#1846

Neighbourhood Watch: A Survey of Baryonic Substructures in the Nearby Universe

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The Neighbourhood Watch is a survey to complete a census of all baryonic structures out to at least the virial radius in a sample of galaxy groups within 18 Mpc in the optical filters u'g'r'i' and H-alpha with CTIO/DECam and in the NIR J,K filters with ESO/VIRCAM. The observations reach unprecedented point source depths of 2.5 magnitudes beyond the peak of the globular cluster luminosity function (GCLF) which will detect >99% of all compact objects, i.e. globular clusters (GCs) and ultra-compact dwarf galaxies (UCDs), and reveal all low-surface brightness baryonic structures down to ~28 mags/arcsec^2. This dataset will allow us for the first time i) to derive a complete GCLF out to the virial radius for these galaxies, ii) search for spatial over-densities and unique age/metallicity distribution functions (ADF/MDF) in the GC population, iii) test current state-of-the-art cosmological simulations by detecting 10-100 new low-surface brightness dwarf galaxies associated with each target group and measure the galaxy luminosity function in different environments, and iv) probe the complex interaction/merger/accretion history of these groups. Thus far we have observed the NGC2997, NGC3115, NGC6744, and NGC4594 groups, complementing related work on the CenA group (Taylor et al. 2017), the Virgo Cluster (NGVS, Ferrarese et al. 2012), and the Fornax Cluster (NGFS, Munoz et al. 2015; Ordenes-Briceno et al. 2018). The project has developed novel observing and data reduction techniques designed to detect the lowest surface-brightness features. This presentation will describe the survey and give initial results.

KEYWORDS galaxies, groups, dwarf, star clusters, survey, spiral

Division H

#1815

What's the boundary between ultra faint dwarf galaxy and low luminosity star clusters?

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Wide-field photometric surveys have discovered a large number of faint stellar systems in the outer halo of the Milky Way, including the ultra-faint dwarf galaxies and low-luminosity star clusters. It has become increasingly difficult to distinguish between these two populations, but the distinction is crucial not only important for the robust determination of the faint end of the galaxy luminosity function, but also for understanding the formation of star clusters at the smallest masses. In this poster, I will show the kinematic and metallicity properties of these faint satellite systems in the Milky Way, in particular, focusing on the latest results from the spectroscopic observations from IMACS spectrograph on the Magellan Baade Telescope.

KEYWORDS star cluster, globular cluster, dwarf galaxy, Milky Way, dark matter, near-field cosmology

Division H

#1633

The CO outflow ejected by a recent accretion burst in B335

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The discrete outflow knots are evidence of a discontinuous accretion process in the growth of stellar mass. In order to understand the direct relation between mass accretion and ejection, we analyze the contemporary accretion activity and outflow in B335. The brightness of B335 in mid-IR has increased since 2010, indicative of an enhanced accretion event. Using the 12CO emission known as an outflow tracer, we found the high-velocity outflow component associated with this recent accretion burst in the position-velocity diagram. The high-velocity outflow component is estimated to have been ejected around 2014. The epoch in which the high-velocity outflow component was ejected is consistent with the epoch of the increase in brightness. This result can be interpreted that the high-velocity outflow component is linked to the recent outburst caused by the recent accretion activity. We also estimate the outflow mass, mass ejection rate, and mass accretion rate for the recent events. Finally, the mass ratio between ejection and accretion for the recent accretion activity is about 0.01, which is lower than the known average value by an order of magnitude.

KEYWORDS Outflow, accretion activity, B335

e-Talks

Division H

#2794

The Optical Imprints of the Vela Jr. Central Compact Object as Seen with MUSE

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Central Compact Objects (CCOs) represent an enigmatic class of isolated neutron stars. Sitting near the centers of young core-collapse supernova remnants (SNRs), they are exclusively visible and studied in the X-ray regime. So far, there has been no firmly identified CCO counterparts at any other wavelengths. However, ground-based observations detected an optical imprint around the location of CXOU J085201.4-461753, the CCO in the heart of Vela Jr. SNR (Pavlov et al., 2001). This object is the only Galactic member of the CCOs class around which optical nebular emission has been detected to date (Pellizzoni et al., 2002, see also Mignani et al. 2019). Originally thought to be Hα emission, the nebulosity was not detected in dedicated narrow-band HST observations (Mignani et al. 2009). Here we present new observations of the young Galactic CCO-hosting Vela Jr. SNR obtained with the Multi-Unit Spectroscopic Explorer (MUSE) integral field spectrograph on the ESO Very Large Telescope (VLT). Our data show that the nebula around the CCO in Vela Jr. glows primarily in the [N II] λλ6548,6583 lines, and further provide a deeper view of the field with an unprecedented sub-arcsecond resolution revealing the imprints of the CCO on its surroundings. We also see signatures of interactions between the nebula and the nearby young stellar object (YSO) associated with the star Ve 7-27, which may provide the most reliable distance determination to the SNR. This would make the Vela Jr. distance the most precisely-measured distance of any Galactic remnant and provide insights into its nature as a powerful cosmic ray accelerator.

KEYWORDS supernova remnants, young stellar object, neutron stars, integral field spectroscopy

DIVISION J

Galaxies and Cosmology

Invited & Contributed Talks

Division J

#1296

Welcome to Division J Meeting!

Kim-Vy Tran[1]

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As current president of Division J, I am honoured to welcome everyone to our Division Days. I will introduce the current Div J Steering Committee and summarise our activities and responsibilities for the current term. I will also include highlights from my resarch program on galaxy evolution across cosmic time.

KEYWORDS galaxy evolution, redshift surveys, gravitational lensing, scaling laws, galaxy formation

Division J

#2716

The Growth of Supermassive Black Holes in the Early Universe

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The existence of luminous quasars hosting supermassive black holes within the first billion years of cosmic history challenges our understanding of black hole growth. An important piece of the puzzle is the lifetime of quasars - the time that galaxies shine as active quasars and during which the bulk of the black hole growth occurs - but to date its value remains uncertain by several orders of magnitude. I will present a new method to obtain constraints on the lifetime of quasars based on the sizes of ionized regions around quasars known as proximity zones. These proximity zones act as a "quasar clock" and enable us to study the co-evolution of supermassive black holes and their host galaxies from a new perspective. Surprisingly, our results indicate that black holes might be able to grow several orders of magnitude faster than previously thought. I will show how future observations with the upcoming James Webb Space Telescope will enable new insights into the early assembly of supermassive black holes and galaxy-quasar co-evolution across cosmic time.

KEYWORDS black holes, quasars, Epoch of Reionization, high-redshift universe

Division J

#797

Kinematic scaling relations for galaxy bulges, disks, and ionized gas from 3D spectroscopy

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Galaxies show a wide range of kinematic properties according to galaxy types. We aim to quantitatively understand the intrinsic distribution of bulge and disk kinematics, and how two components describe the overall distribution of stellar kinematics of galaxies. The spatially-resolved rotation velocity and the velocity dispersion of bulge and disk components have been simultaneously estimated for the SAMI 3D spectroscopy data using the penalised pixel fitting method. Kinematic scaling relations demonstrate that the galaxy stellar mass scales with kinematics for both bulge and disk components of all galaxy types, which suggests kinematics of two components are less dependent on galaxy populations and largely determined by the mass. We quantitatively show that the bulge and disk components are kinematically distinct: the two components show scaling relations with similar slopes, but different intercepts; the spin parameter λR indicates bulges (disks) are pressure(rotation)-dominated systems. Our findings suggest that the relative contributions of bulge and disk components explain, at least to first order, the complex kinematic behaviour of galaxies according to galaxy type. On the other hand, kinematics of ionized gas are significantly impacted by power sources (e.g. star formation, AGN, and old stars), unlike stellar kinematics. For star-forming galaxies, the stellar velocity dispersion tends to be larger than the gas velocity dispersion, suggesting that stars are, in general, dynamically hotter than the ionized gas (asymmetric drift). However, AGN show gas velocity dispersions comparable to stellar ones, implying their gas kinematics have been dynamically heated by AGN activities (e.g. outflows).

KEYWORDS galaxy kinematics, scaling relations, bulges and disks, active galactic nuclei

Division J

#816

Lyα Radiative Transfer in Continuous and Clumpy Spherical H I Halo with a Central source

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The origin of Lyα emitting nebulae, which extend over ~100 kpc and may mark regions of early galaxy cluster formation, is still controversial. Possible mechanisms include photoionization by AGN, cooling radiation from cold accretion, shocks by galactic outflows, and scattering of Lyα by the nebular gas. In this work, we simulate the scattering of Lyα in an H I halo about a central Lyα point source. For the first time, we consider smooth and clumpy halos, a range of halo expansion velocities, H I column densities, covering factors and concentrations, and AGN or star-forming central sources. We compute the spatial and frequency diffusion and the polarization of the Lyα photons through scattering. We find two general classes of Lyα nebula morphologies: with and without bright cores. The cores are seen when the column density is low, i.e., when the central source is directly visible, and are associated with a polarization jump, a steep increase in the polarization prole near the halo center. Another result is a 100 kpc Lyα nebula with L(Lyα) = 10^43 erg s^-1 and z=3 when a covering factor f_c>2 and a column density N_HI 10^20 cm^-2. This N_HI works for the formation of the large nebula in a continuous medium. We find that symmetric Lyα line at the systemic velocity can only arise from a clumpy medium for low covering factor (f_c < 2). Of all the parameters tested, the H I column density dominates the trends. This presentation shows the simulated results of Lyα halo composed of Lyα scattered from a point source surrounding a smooth and clumpy H I medium.

KEYWORDS Radiative Transfer, Lyman Alpha, Polarization, Lyman Alpha Nebulae

Division J

#1544

Dust emission templates for star-forming galaxies in the era of JWST

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The bolometric dust emission provides critical information for tracing star formation across cosmic times. Measuring it is a difficult and complex affair, however, and the launch of JWST highlights the need for new dust emission templates that provide an un-biased view of galaxies. Indeed, in the absence of adequate and detailed templates, the limited spectral coverage of JWST may negatively affect our ability to estimate the bolometric dust emission to trace star formation. Existing templates from local luminous samples are not necessarily representative of similarly luminous galaxies at higher redshifts. In effect, when applied to higher redshifts, some of the existing templates are suspected to produce systematic offsets in LTIR derived from MIR monochromatic luminosities. Efforts to produce IR templates using the actual high-redshift galaxies have made significant progress in recent years, primarily as the result of the stacking of Herschel observations. For now, the focus has been mostly on producing average templates in various redshift bins, which cannot capture the diversity of dust emission properties present at a given redshift. In this communication, we present a recent effort to build new dust templates for the JWST era, combining state-of-the-art observations and models. In particular, we show that these new templates allow us to obtain fresh insights regarding the interplay between monochromatic IR luminosities, spectral shapes, and physical properties, while also providing remarkably precise estimates of the dust luminosity with a single band over the rest-frame 12-17 and 55-130 microns.

KEYWORDS dust emission, JWST, templates

Division J

#2295

Quasars and the intergalactic medium at cosmic dawn

Xiaohui Fan[1]

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High-redshift quasars provide direct probes to the formation of the earliest supermassive black holes, their connections to early galaxy formation, and the history of cosmic reionization. More than 200 quasars have now been discovered in the first billion years of the cosmic history, with the highest redshift currently at z=7.6, indicating that billion solar mass black holes have already fully formed merely half billion years after the first star formation in the universe. I will (1) review the current state of high-redshift quasar surveys and discoveries, as a result of the new generations of wide-field sky surveys and developments in data mining and machine learning; (2) discuss using high-redshift quasars as probes to the history of supermassive black hole growth in the early universe, using measurements of quasar luminosity function and black hole masses; (3) present the latest observations of the the co-evolution of early SMBH growth and galaxy formation, and the roles quasar played in early galaxy formation and structure formation; and (4) review the progress of using IGM absorption in quasar sightlines and properties of quasar proximity zones, which is unveiling a rapid and highly inhomogeneous reionization process at z~5.5 - 7.5. I will close with a discussion about the future of high-redshift quasar research, in the context of future facilities such as JWST, LSST and Roman Space Telescope.

KEYWORDS quasar, supermassive black hole, reionization, galaxy formation

Division J

#2641

(Re)solving Reionization with Lyman-alpha emission

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Reionization marks the last major phase transition of matter in the Universe and its completion had crucial impact on the formation of the smallest galaxies. Reionization is therefore the first landmark of the influence that feedback from star formation had on structure formation. While reionization roughly encapsulated the first Gyr of cosmic time, the precise timing, topology and the sources of ionizing photons are unknown. Did reionization proceed rapidly or gradually and was it driven by rare bright galaxies, or numerous faint ones? The key uncertainty is the ionizing photon escape fraction (LyC Fesc), and how this varies among galaxy properties. In my talk I will argue to tackle this problem based on measurements of resolved Lyman-alpha (LyA) emission from the X-SHOOTER LyA survey at z=2 (XLS-z2). I will show observational evidence that the defining traits of LyC leaking galaxies are highly ionising stellar populations, low column density gas and a dust-free, high ionization state ISM. This is evidence that galaxies leak ionising photons (with LyC Fesc 20-50 %) when the hottest stars are still shining. Motivated by these results, I will present a model of a LyA Emitter-dominated emissivity that explains the relative flatness of the total galaxy emissivity over z~2-8 and the reionization of the Universe by z~6 under reasonable assumptions, thus naturally accounting for the strong evolution of the average LyC Fesc of the full galaxy population between redshifts z~2-8. In a fiducial choice of model parameters, the "disco" emissivity is dominated by a strong minority of galaxies with intermediate mass (~10^8 Msun). I will conclude with proposed observational tests to further develop the LyA-anchored formalism, with a particular emphasis on blind emission-line surveys with the JWST.

KEYWORDS galaxy formation, reionization, galaxy evolution, observations, spectroscopy

Astronomy for All
Busan 2022

Division J

#1855

Discovery of Two New z~6 Quasars with IMS and Space Density down to M1450 ~ -23.5 mag

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We present the result of the Infrared Medium-deep Survey (IMS) z ~ 6 quasar survey, using the combination of the IMS near-infrared images and the Canada-France-Hawaii Telescope Legacy Survey (CFHTLS) optical images. The traditional color-selection method results in 25 quasar candidates over 86 deg2. We introduce the corrected Akaike Information Criterion (AICc) with the high-redshift quasar and late-type star models to prioritize the candidates efficiently. Among the color-selected candidates, seven plausible candidates finally passed AICc selection of which three are known quasars at z ~ 6. The follow-up spectroscopic observations for the remaining four candidates were carried out, and we confirmed that two out of four are z ~ 6 quasars. With this complete sample, we revisited the quasar space density at z ~ 6 down to M1450 ~ -23.5 mag. Our result supports the low quasar space density at the luminosity where the quasar's ultraviolet ionizing emissivity peaks, favoring a minor contribution of quasars to the cosmic reionization.

KEYWORDS Quasars, Active Galactic Nuclei, Reionization, Early Universe, Sky surveys, Observational astronomy

Division J

#1555

Searching for extragalactic HI 21-cm absorption: Early results from the ASKAP-FLASH pilot observations

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We report the latest results from the First Large Absorption Survey in HI (FLASH), an untargeted survey searching for 21-cm line absorption at $0.4 < z < 1.0$ across the entire sky south of declination +40 deg. The survey has just finished two phases of 100-hr pilot observations with the Australian Square Kilometre Array Pathfinder (ASKAP), covering around 3000 square degrees of the sky. During the pilot surveys we successfully detected both associated and intervening 21-cm absorbers, which are highly related to the adjacent host galaxies and distant background radio sources, respectively. We will highlight some of the newly detected spectra and present how we trace the origin of 21-cm line absorption based on the narrow or broad spectral lines. In addition to the wide-band spectra, the pilot observations provide high-quality 856 MHz wide field continuum images of each field (rms ~ 90 μJy/beam). We also carried out supplementary multi-wavelength observations, which enable us to investigate the star-formation rates and other properties of galaxies surrounding the 21-cm sightline. Recent VLBI images obtained with e-MERLIN and KVN observations will be presented to discuss the relation between the properties of absorption and background radio sources.

KEYWORDS galaxies: active, galaxies: evolution, quasar: absorption lines, radio lines: galaxies, radio continuum: general

Division J

#2425

Tracing the origin of intracluster stars with Horizon Run 5

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Observations have shown that a significant fraction of the stars in galaxy clusters are floating, not gravitationally bound to any individual member galaxies. Both nature and origin of these intracluster stars have been a subject of active research in frontier astronomy based on state-of-the-art instruments, data processing algorithms, and numerical simulations. Although remarkable progress has been made over the past few decades, there still remain several competing theories that need to be tested with future next-generation telescopes and simulations. Horizon Run 5 is a cosmological hydro simulation, which reproduces physical scales ranging from ~1 kpc to ~1 Gpc. This is a useful tradeoff between resolution and volume for studies of intracluster stars given the current computational resource limit. We utilize the output of the PSB-based galaxy finder to identify intracluster stars and trace their evolution with the aim to constrain the origin. In addition, we generate mock optical images of galaxy clusters and investigate how well existing observational techniques can recover the true properties of the intracluster stars. We discuss our results from ~200 clusters/groups in Horizon Run 5.

KEYWORDS ICL, galaxy clusters, numerical simulations

Division J

#1989

Intracluster Light Study of the Galaxy Clusters at z > 1 with Hubble Space Telescope WFC3/IR Data

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Intraclusterlight (ICL) is diffuse light from stars that are bound to the cluster potential, but not to individual members. The formation mechanism of ICL can provide important information on the history of the galaxy cluster. There are several competing theories, including relaxation of BCG and stripping of massive satellites, but the dominant production mechanism is still in dispute. With an aim to differentiate competing theories, we studied ICL at redshifts greater than 1 using deep HST/WFC3 IR imaging data. After applying our customized pipeline for sky estimation and object masking, we measured ICL over 100 kpc from the center of BCG. Using multiple Sérsic profiles, we successfully decomposed the diffuse light into the ICL and BCG components. The mean Sérsic index of the ICL component is about 1.77. We found that the stacked color profile of our target shows a non-significant gradient. Furthermore, our stellar population synthesis analysis prefers old and metal-poor populations for most BCGs and intracluster stars. The mean ICL fraction of our targets is about 18.3%, which is not significantly different from previous studies at a low redshift. When we compared our results and previous studies, the ICL fraction shows no significant correlation with redshift or mass. Therefore, our high-z result supports the theory that most intracluster stars are produced in tandem with the BCG formation.

KEYWORDS Galaxy Cluster, Intracluster Light

Division J

#1537

Water Silhouettes against the Cosmic Microwave Background from the Most Distant Starburst Galaxies

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Astrophysical objects can imprint distortions on the observed Cosmic Microwave Background (CMB) that give access to information for cosmology research that cannot be obtained otherwise. ΛCDM cosmology implies a linear scaling of the CMB temperature (TCMB) with redshift z, but departures of this linear scaling behavior are allowed in more complex, but currently poorly observationally constrained cosmological models, such as those that include an evolution of physical constants, decaying dark energy, or axion-photon-like coupling processes. In this presentation, I will introduce a new method to directly measure TCMB out to z>6 based on H2O absorption against the CMB, and describe our findings based on an initial detection towards the massive dusty starburst galaxy HFLS3 at z=6.34. This far exceeds the redshift range where direct TCMB measurements across cosmic time have been previously possible, providing a crucial test of standard cosmology.

KEYWORDS galaxies: starburst, galaxies: high-redshift, cosmic microwave background, early universe, submillimeter, radiative transfer, ISM: molecules

Division J

#787

Sharpening our View of Dust Attenuation using the TYPHOON survey

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A description of dust attenuation curves and how they evolve with time is a critical ingredient of future precision studies of distant galaxies. To date, there has been little work on establishing the extent to which attenuation curves vary within galaxies and which is will be of critical importance to maximize returns from current and imminent facilities capable of high resolution optical and near-infrared imaging and spectroscopy (e.g., VLT, JWST, ELT). Using the TYPHOON survey that obtained optical IFS data of 44 nearby, large-angular size (>few arcmin) galaxies, together with ancillary data spanning ultraviolet to infrared wavelengths, we will develop a revolutionary understanding of how light from galaxies is affected by dust attenuation at varying spatial scales (~20-100pc) and as a function of galaxy properties, such as the gas-phase metallicity. I will present a characterization of the variation of dust attenuation curves as a function of various galaxy properties. I will discuss the implications of these results on the application of dust attenuation curves at higher redshifts. I will also present an overview of the TYPHOON survey and data products that will be made publicly available for legacy science to study spatially-resolved properties of nearby galaxies.

KEYWORDS

Division J

#1943

Nox: 12U CubeSat Mission Concept for Characterizing All-Sky FUV Background

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We present a new mission concept, Nox, a 12U CubeSat designed to map the all-sky EUV and FUV background. The EUV and FUV emission from the hot and warm-hot circumgalactic and intergalactic medium (CGM, IGM) is extremely faint, possibly below 33 LU (1E-20 erg/s/cm^2/arcsec^2 at 1500 A). A precise knowledge of the sky background level is essential to detect such faint features. Uncertainty in the background level can lead to several orders of magnitude differences in the required exposure time to reach a target sensitivity. Currently, the strength of the FUV continuum background is poorly known over a limited wavelength range with low (R~3) spectral resolution, varying between 330 to 3300 CU (1E-19 to 1E-18 erg/s/cm^2/arcsec^2/Angstrom at 1500 A).

Nox will create a foundational baseline for all future UV missions that seek to detect faint diffuse objects in the sky. Nox will conduct an all-sky spectroscopic survey in the entire LUV and FUV wavelength bands, from 90 nm to 240 nm, with a spectral resolution R > 25, within 14 months on-orbit mission lifetime. This range covers important airglow lines in low-Earth-orbit, which are also critical for future missions to estimate in-band or out-of-band scattered light from bright airglow lines.

An all-sky survey with a 12U CubeSat is made possible with two spectroscopic channels, each optimized to detect low-surface brightness faint EUV and FUV sky with high etendue (Field of view = 7 deg. x 1 deg.). Nox will advance the Technical Readiness Level of multiple key technologies for the future large IR/O/UV mission, where the Astro2020 Decadal recommends the mission. Those technologies include the UV-sensitive detector, humidity-resistant high reflectivity UV mirror coatings, and the high-groove density, low-scattering, and aberration control grating technologies. We proposed Nox to NASA Astrophysics Research and Analysis program in Dec. 2021.

KEYWORDS CGM, IGM, EUV, FUV, CubeSat, Technology, Nox

Division J

#2412

The cosmic web of galaxies seen in X-ray by eROSITA

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In this presentation, I will discuss how the cosmic web of galaxies and their circum galactic medium (CGM) is seen by the new SRG/eROSITA soft X-ray telescope.

The CGM plays an important role in galaxy evolution as the main interface between the star-forming body of galaxies and the surrounding cosmic network of in- and out-flowing matter. In a recent analysis, we stacked X-ray events from the 'eROSITA Final Equatorial Depth Survey' (eFEDS) around central galaxies in the 9hr field of the 'GAlaxy and Mass Assembly' (GAMA) survey to construct radially projected X-ray luminosity profiles in the 0.5–2 keV rest frame energy band as a function of their stellar mass and specific star formation rate. We consider samples of quiescent (star-forming) galaxies in the stellar mass range 2×10^{10}-10^{12} Msun (3×10^{9}-6×10^{11} Msun).

We measure for the first time the mean relation between average X-ray luminosity and stellar mass separately for quiescent and star-forming galaxies when including or masking active galactic nuclei as well as their luminosity profiles. I will discuss its meaning and implications by comparing the results with state-of-the art numerical simulations.

This work is a stepping stone towards a more profound understanding of the hot phase of the CGM, which holds a key role in the regulation of star formation and galaxy formation. I will conclude the analysis with forecast of upcoming analysis using the full eROSITA all-sky survey data, combined with future generation galaxy evolution surveys, that shall provide much enhanced quantitative measures and mappings of the circum-galactic medium and its hot phase(s) and its relation to the overall galaxy population.

KEYWORDS galaxies, CGM, X-ray, survey

Division J

#376

HI mapping of nearby dwarf galaxies with SKA pathfinders: unique capabilities of KAT-7 and MeerKAT

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Dwarf galaxies are by far the most numerous galaxies in the Local Universe. Their simple structure and proximity provide a unique window to the detailed investigation of various processes necessary for galaxy formation and evolution. One of the most reliable approaches for studying the evolution of galaxies is to look at their physical properties using neutral hydrogen gas (HI). In this talk, I will present ongoing work on the HI properties of dwarf galaxies with SKA path-finders. I will also report the discovery of large amounts of cold HI gas in a nearby galaxy group. The observations were obtained with South Africa's MeerKAT-64 array as part of the early science program. The sensitivity of MeerKAT allowed us to detect a complex web of low-surface brightness HI emission. Dwarf galaxies are by far the most numerous galaxies in the Local Universe. Their simple structure and proximity provide a unique window to the detailed investigation of various processes necessary for galaxy formation and evolution. One of the most reliable approaches for studying the evolution of galaxies is to look at their physical properties using neutral hydrogen gas (HI). In this talk, I will present ongoing work on the HI properties of dwarf galaxies with SKA path-finders. I will also report the discovery of large amounts of cold HI gas in a nearby galaxy group. The observations were obtained with South Africa's MeerKAT-64 array as part of the early science program.

KEYWORDS galaxies, kinematics, star formation

Division J

#2883

New empirical constraints on the cosmological evolution of gas and stars in galaxies

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The technique of intensity mapping (IM) is a novel tool to investigate galaxy formation and evolution, by measuring the integrated emission from sources over a broad range of frequencies. A particular advantage of IM is that it provides a tomographic, or three-dimensional picture of the Universe, unlocking several thousand times more independent modes of information than one can obtain from conventional probes. In addition to hydrogen (the most abundant element), there are exciting prospects for using intensity mapping in the submillimetre wavelengths, from the carbon monoxide (CO), ionized carbon and oxygen ([CII] and [OIII]) lines, as tracers of the interstellar medium in galaxies. I will illustrate how the description of dark matter haloes can be extended to model the abundances and clustering of molecular and ionic species with IM data. Combined with the latest observationally motivated constraints on stellar properties in dark matter haloes, this allows us to derive empirical relationships between the build-up of galactic components and their evolution over cosmic time. Our results elucidate several key features of the baryon cycle in galaxies, including the relative contributions of mergers and smooth accretion to gas mass assembly, and the dependence of the star formation rate on atomic and molecular gas depletion timescales.

KEYWORDS galaxies:star formation, galaxies:evolution, intensity mapping

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#687

Dusty quasars eject star-forming gas from galaxies at cosmic noon

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The canonical picture of galaxy evolution invokes strong feedback from active galactic nuclei (AGN) to reduce the star formation efficiency of massive galaxies. This process can explain their observed scaling relations, which were already established by cosmic noon (z=2-3). However, the physical channels that allow energy and momentum released on sub-pc scales to affect gas on galactic scales are largely unconstrained. In this presentation, I show a direct link between dust-reddening and molecular outflows from quasars at z~2.5. By examining the dynamics of warm molecular gas in the inner regions of galaxies, we detect outflows from within the galactic bulges (~100 pc)) with short timescales of 0.05 Myr that are due to ongoing energy output from the AGN. We observe outflows only in systems where quasar radiation pressure on dust is sufficiently large to expel their obscuring column densities, indicating that radiative feedback regulates gas in the nuclear regions of galaxies. This is in agreement with theoretical models that predict radiation pressure on dust in the vicinity of the black hole is a major driving mechanism of galactic-scale outflows of cold gas. Our findings show that quasar radiation ejects star-forming gas from nascent stellar bulges at velocities comparable to those seen on larger scales in ionised gas, and that molecules survive in outflows even from the most luminous quasars.

KEYWORDS AGN, galaxies, ISM, quasars, feedback, high-z

Division J

#1498

Results from the MeerHOGS

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The MeerKAT Habitat of Galaxies Survey (MeerHOGS) makes use of the large field-of-view and the sensitivity of the MeerKAT radio telescope. We targeted a cosmic filament at redshift 0.03 as identified in the 2dF Galaxy Redshift Survey and the Galaxy and Mass Survey (GAMA) G23 field. The 16-hour mosaic observation covers a total area of 5-10 square degrees, depending on the choice of the limiting sensitivity. Roughly 200 galaxies are detected in total. MeerHOGS, despite being modest in terms of observing time, hence enables us to characterize the HI and continuum population of the filament and to explore scaling relations, in a field also covered by a set of ancillary observations. While being able to characterize the neutral gas content and scaling relations in the global galaxy population, we could also identify particularly interesting objects. An example is the extremely warped IC 5271, which has presumably undergone a tidal interaction or captured gas from a companion galaxy yet to be identified. We also report on the discovery of a massive dark cloud complex without any significant optical counterpart. The complex with 10 billion solar masses shows 7 concentrations. Using KIDS r-band imaging the HI mass-to-light ratio of the most massive knot with 5 billion solar masses is larger than 1000. No optical counterpart could be identified. Such larger clouds or cloud complexes, which are detached from an adequately massive stellar body, from which they could originate, are, to date, very rare. While single-dish surveys constrain the frequency of such cloud complexes, interferometric observations have the resolving power to separate isolated clouds from galaxies. Hence, blind HI surveys with the SKA and its progenitors might reveal more such objects.

KEYWORDS Surveys, Neutral hydrogen, Radio continuum, Cosmic filaments, Dark clouds

Division J

#518

A Unified Scenario for the Origin of Spiral and Elliptic Galaxy Structural Scaling Laws

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Elliptical (E) and spiral (S) galaxies follow tight, but different, scaling laws linking their stellar masses, radii, and characteristic velocities. Mass and velocity, for example, scale tightly in spirals with little dependence on galaxy radius (the "Tully-Fisher relation"; TFR). On the other hand, ellipticals appear to trace a 2D surface in size-massvelocity space (the "Fundamental Plane"; FP). Over the years, a number of studies have attempted to understand these empirical relations, usually in terms of variations of the virial theorem for E galaxies and in terms of the scaling relations of dark matter halos for spirals. We use Lambda Cold Dark Matter (LCDM) cosmological hydrodynamical simulations to show that the observed relations of both ellipticals and spirals arise as the result of (i) a tight galaxy mass-dark halo mass relation, and (ii) the selfsimilar mass profile of CDM halos. In this interpretation, E and S galaxies of given stellar mass inhabit halos of similar mass, and their different scaling laws result from the varying amounts of dark matter enclosed within their luminous radii. This scenario suggests a new galaxy distance indicator applicable to galaxies of all morphologies, and provides simple and intuitive explanations for long-standing puzzles, such as why the TFR is independent of surface brightness, or what causes the "tilt" in the FP. Our results provide strong support for the predictions of LCDM in the strongly non-linear regime, as well as guidance for further improvements to cosmological simulations of galaxy formation.

KEYWORDS galaxies, scaling, size, velocity, tully-fisher, faber-jackson

Division J

#589

Bar Formation and Star Formation Enhancement in Disk Galaxies in Interacting Clusters

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A merger or interaction between galaxy clusters is one of the most violent events in the universe. Thus, interacting clusters are optimum laboratories to understand how galaxy properties are influenced by the drastic change of the large-scale environment. Here, we present the observational evidence that bars in disk galaxies can form by cluster-cluster interaction and the bar formation is associated with star-formation enhancement. We investigate 105 galaxy clusters at $0.015<z<0.060$ that are detected from the Sloan Digital Sky Survey data. Among them, 16 clusters are identified as interacting clusters. We find that the barred disk galaxy fraction is about 1.5 times higher in interacting clusters than in clusters with no obvious signs of interaction (42% versus 27%). For disk galaxies with $10.0<\log M_{star}<10.4$, the increase of the bar fraction is accompanied by star formation enhancement, so that the fraction of star-forming galaxies is about 1.2 times higher in interacting clusters than in non-interacting clusters. Our results indicate that cluster-cluster interaction is an important mechanism that can induce bars and star formation in disk galaxies.

KEYWORDS Barred spiral galaxies, Galaxy environments, Galaxy clusters, Tidal interaction, Star formation, Galaxy evolution

Division J

#1935

Tools for Measuring the Cosmic Molecular Gas History

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The evolving cosmic abundance of cold molecular gas, along with its connection to the history of star formation, is an area of great interest in galaxy evolution. Advances in millimeter-wave instrumentation have resulted in exciting advances in this field through the study of CO emission lines, with ALMA, JVLA, and PdBI/NOEMA all conducting deep-fields surveys in search of high redshift CO emission during the past decade. However, studies conducted with these facilities are limited to relatively small areas of sky. Interpreting the results requires careful accounting for the effects of cosmic variance, and corrections for objects too uncommon to be found in the survey volume. I will present the result of our recent work attempting to quantify these uncertainties using mock observations of the IllustrisTNG simulation. I will then discuss CO line intensity mapping (LIM), an alternative survey approach that images large cosmological volumes at low sensitivity and extracts the aggregate CO signal from intensity fluctuations captured by the power spectrum of the map. LIM enables surveys over much larger volumes and can recover information about galaxies fainter than the threshold for direct detection, making it an excellent complement to previous projects. I will present our group's recent LIM results, with a focus on our upper limits on the CO-galaxy cross-power spectrum. These results have served as a proof of concept for LIM studies and already demonstrate their power to constrain cosmic molecular gas abundances.

KEYWORDS Galaxy Evolution, ISM, Molecular Gas

Division J
#689

The Diffuse Ionized Gas of the Magellanic System

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The Magellanic Cloud System is an excellent observational target for exploring the warm ionized medium (WIM), acting as a bridge between Milky Way observations and extragalactic observations. Hα emission from the WIM is often faint (>1 R), requiring highly sensitive instruments to observe its full extent. Previous surveys of the Diffuse Ionized Gas (DIG) only extended down to a few Rayleighs, requiring a highly specialised telescope to observe the diffuse gas. Using the Wisconsin-Alpha Mapper's (WHAM) highly sensitive spectrograph (~20 mR), our survey of Hα emission provides the first comprehensive look at the diffuse ionized gas content of the Magellanic Cloud System.

Here we present the combined results from the Large and Small Magellanic Cloud surveys with early results from the Magellanic Stream Survey to provide a comprehensive picture of the diffuse ionized gas content in the Magellanic System, exploring the morphology, velocity, and mass of the ionized gas. With the completion of the Small Magellanic Cloud Survey and the Large Magellanic Cloud Survey, many previously unknown ionized structures have been revealed, expanding our understanding of the structure of the galaxies. Ionized features extending out towards the Leading Arm (LA) and the Stream give us further clues to the impact galaxy interactions have had on the system. Mass estimates for the SMC and LMC suggest a more significant ionized gas fraction than previously estimated. The addition of the Stream reveals the Hα emission continues beyond the galaxies alongside the neutral hydrogen Stream, with ionized gas seen along the full 120 degree extent of the Stream survey. Combined, the observations cover gas with velocities between -400 km/s and 400 km/s and span a region over 120x40 degrees across the sky with a velocity resolution of 12 km/s. Together, all three surveys reveal a highly ionized system disturbed by galaxy interactions, and provides new insight into the morphology and velocity structure of the diffuse ionized gas.

KEYWORDS galaxies: ISM, Galaxies: Magellanic Clouds, galaxies: structure, galaxies: dwarf, ISM: kinematics and dynamics, ISM: kinematics and dynamics, DIG

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#2750

Neutrino and dark matter cosmology with the Lyman-alpha forest

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Neutral hydrogen in the Intergalactic Medium produces a collection of Lyman-alpha (Lya) absorbtions, called the Lya forest, seen in the spectra of background objects. According to the common paradigm, neutral hydrogen in the IGM evolves from primordial density fluctuations in a low density and photo-ionized environment. It therefore acts as a direct tracer of Dark Matter (DM). However, it also implies that temperature and density are thightly coupled, giving rise to degeneracies between parameters describing either cosmology or the IGM thermal history. The Lya forest 1D power spectrum is sensitive to clustering on small scales, and as such to the smoothing scale of relativistic particles. It has been used to put the strongest constraints on the sum of the neutrino masses and to study DM models. To infer cosmological constraints and to test our models at the percent level accuracy, the measurements need to be compared to state-of-the-art hydrodynamical simulations. We also need to refine our understanding of the impact of galactic feedbacks on the IGM temperature.

I will present the analysis that leads to the most recent P1D measurement. As the current uncertainties are at the percent level, and will even shrink further in the DESI era, we need to improve the numerical modeling of the Lya forest. In particular, we need to take into account complex mechanical effects known as AGN feedback. We use Adaptative Mesh Refinement (AMR) hydrodynamical simulations, the Horizon-AGN and Horizon-noAGN simulations, to evaluate its impact on the P1D and prevent degeneracies with neutrino effects. Finally I will present the most up-to-date constraints on the mass of active neutrinos and on Warm Dark Matter models.

KEYWORDS Lya forest, cosmology, neutrinos, dark matter, simulations, feedback

e-Posters

Division J

#3408

Galactic-scale magnetic fields in distant galaxies

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Magnetic fields play an important role in galaxy formation and evolution as they can affect gas dynamics, star formation rate, and the initial mass function. However, as there are only a handful of measurements outside of the local Universe, their redshift evolution is not well constrained. Nevertheless, we can directly measure the magnetic field strength of distant galaxies by observing background quasars gravitationally lensed by foreground galaxies demonstrated by Mao et al. 2017, who measured μG magnetic field in a galaxy at z=0.4. We can determine the Rotation Measure (RM) of the polarized lensed images, which is the integral of the line of sight magnetic field and the electron density. The differential RM between the lensed images can be mainly attributed to the magneto-ionic medium of the lensing galaxy, providing us with information on the strength and structure of its magnetic field.

We obtained broadband polarization data of the two-image lensing systems, CLASSB1600+434 and CLASSB0218+357, at 1-8 GHz using the Jansky VLA. The high angular resolution measurements separate the lensed images, and the broadband data allows us to resolve multiple polarized components in Faraday depth space. The lensing galaxies of CLASSB1600+434 and CLASSB0218+357 have a redshift of 0.41 and 0.685, respectively. In both galaxies, we trace the magnetic field strength of the halo. We find Bvertical = 0.1 - 5.2 μG in the lensing galaxy of B1600+434, and Bvertical > 0.34 μG in the lensing galaxy of B0218+357. This is the first time halo magnetic field strengths have been constrained in galaxies at z>0. These measurements can put a tighter limit on the amplification time scale of the large-scale magnetic field of galaxies, which in turn can improve our understanding of galaxy evolution.

KEYWORDS galaxies: ISM, galaxies: magnetic fields

Division J
#3396

Magnetised HI Filaments in the Small Magellanic Cloud from the GASKAP-HI Survey

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Diffuse atomic (HI) gas in the interstellar medium is organised into vast networks of filamentary structures, with magnetic fields controlling their internal gas dynamics and macroscopic morphology. In-depth studies of the relationship between HI filaments and the strength and structure of the magnetic fields permeating through them are therefore crucial for our understanding of how atomic gas condenses into molecular gas leading to eventual star formation. Furthermore, such studies can be further applied as probes of the galactic-scale magnetic field and turbulence in the interstellar medium. The case study of the Small Magellanic Cloud (SMC) is particularly interesting, since similar low-mass low-metallicity dwarf galaxies are ubiquitous in the early Universe. We investigate in the HI filaments in the SMC using new data from the Australian Square Kilometre Array Pathfinder (ASKAP) for the Galactic ASKAP HI (GASKAP-HI) survey. A novel ray-tracing algorithm has been developed and applied to the new HI images of unprecedented quality to carefully compare with existing starlight polarisation measurements tracing the magnetic fields in the SMC. Our study shows that the HI filaments in the main body (Bar region) of the SMC are preferentially aligned with the ambient magnetic field, while they show signs of anti-alignment with magnetic field in the tidal structure (Wing region). In this poster, we will discuss the implications of our results on the magnetic field structure of the SMC.

KEYWORDS

Division J

#3362

A merging supermassive black hole or disk emitter system in a red active galactic nucleus

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2MASS J165939.7+183436 (1659+1834) is a red active galactic nucleus (AGN) at z=0.170, and it has been suspected to have a merging SMBHs due to its (i) merging features found in Hubble Space Telescope imaging; (ii) double-peaked broad emission lines (BELs) in hydrogen Balmer and Paschen lines. We observe 1659+1834 using the GMOS IFU on the Gemini North telescope to obtain the spatially resolved Hα line. We find the two BEL components are spatially separated at 0.085" (~250 pc in physical scale) and confirm the existence of two BEL peaks that are kinematically separated by ~3000 km/s. However, the spatial separation can be changed in the different spectral fitting assumptions, from a null (<0.05") to a larger (~0.15") spatial separation. Therefore, various models, such as the merging SMBH and the disk emitter models, can explain the double BELs of 1659+1834.

KEYWORDS AGN, SMBH, Galaxy evolution, Galaxy mergers, Quasar

Division J

#3339

KS4 Massive Galaxy Cluster Candidates in the Southern Sky

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Galaxy clusters are the largest structures in the universe located at the top of the cosmological hierarchical model, so the evolution of the universe can be understood by studying clusters of galaxies. Therefore, finding a larger number of galaxy clusters plays an important role in exploring how the universe evolves. A large number of catalogs for galaxy clusters in the northern sky have been published; however, there are few catalogs in the southern sky due to the lack of wide sky survey data. KMTNet Synoptic Survey of Southern Sky(KS4) project, which observes a wide area of the southern sky about 7000 square deg with KMTNet telescopes for two years, is in progress under the SNU Astronomy Research Center. We use the KS4 multi-wavelength optical data and find massive galaxy clusters at redshift z<1 using the cluster red-sequence method. This will improve the study of galaxy clusters in the southern sky.

KEYWORDS cluster, galaxies, catalog

Division J

#3331

Lyman alpha emitters and Lyman-break galaxies as tracers of large-scale structures in a simulated universe

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To understand whether high-redshift star-forming galaxies including Lyman alpha emitters (LAEs) and Lyman-break galaxies (LBGs) are good tracers of large-scale structures in the universe, we analyze the cosmological hydrodynamic simulation data of Horizon Run 5. First, we identify LAEs and LBGs at z=2.4-4.5 using the selection criteria of narrow- and broad-band photometry for the simulated galaxies as in observations. We then apply the DISPERSE code to those LAEs and LBGs as well as all galaxies and dark matter particles to define the filamentary structure for each tracer. The overall shapes of filamentary structures from different tracers look similar, but their detailed features appear slightly different. Next, we adopt the filamentary structures of dark matter particles as reference to calculate the distance of each tracer to its closest filament, D_skel. We then compare the distributions of D_skel for different tracers, and find that LBGs and LAEs are more concentrated toward the filament than all galaxies and dark matter particles. These results suggest that LAEs and LBGs can be good tracers of large-scale structures in the universe at high redshifts.

KEYWORDS Cosmology, Large-scale structure of the universe, Hydrodynamical simulations, High-redshift galaxies

Division J

#3251

Understanding the diverse rotation curves of nearby galaxies with the cosmological hydrodynamical simulation

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Recent integral field spectroscopic observations have shown that galaxy rotation curves are diverse in their radial dependence. To understand the physical origin of this diversity of galaxy rotation curves, we analyze the cosmological hydrodynamic simulation data of IllustrisTNG. We first select the galaxies with stellar mass larger than 3.4 × 108 $M_\odot$ and total mass smaller than 1013 $M_\odot$ from TNG50 to make a sample comparable to that of observations. We then derive rotation curves of galaxies using the enclosed mass at each galactocentric radius, and determine the slope in the outer region. The outer slopes of the simulated galaxies show diverse patterns, which is consistent with observational results. We examine the relation between the outer slope and the galaxy properties, and successfully reproduce the observed dependence of the outer slope on stellar mass and morphology. The outer slope decreases as galaxies are more massive in terms of stellar mass, and increases as galaxies are more disky. The outer slope of the rotation curves seems to be affected by galaxy formation histories, which are closely related to physical parameters including dark matter and gas fractions.

KEYWORDS Galaxy rotation curves, Galaxy dynamics, Hydrodynamical simulations, Galaxy evolution, Galaxy kinematics, Astronomical simulations, Cosmology

Division J

#3304

Galaxy Properties of Nearby Cosmic Filaments

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We present the properties of galaxies in filaments around the Virgo cluster with respect to their vertical distance from the filament spine using the NASA–Sloan Atlas catalog. The filaments are mainly composed of low-mass, blue dwarf galaxies. We observe that the g − r color of galaxies becomes blue and stellar mass decreases with increasing vertical filament distance. The galaxies were divided into higher-mass ($\log(h^2M^*/M_\odot) > 8$) and lower-mass ($\log(h^2M^*/M_\odot) < 8$) subsamples. We also examine the distributions of g − r color, stellar mass, Hα equivalent width (EW(Hα)), near-ultraviolet (NUV) − r color, and HI fraction of the two subsamples with the vertical distance. The lower-mass galaxies exhibit a negative g − r color gradient, whereas higher-mass galaxies have a flat g − r color distribution. We observe a negative EW(Hα) gradient for higher-mass galaxies, whereas lower-mass galaxies show no distinct EW(Hα) variation. In contrast, the NUV − r color distribution of higher-mass galaxies shows no strong trend, whereas the lower-mass galaxies show a negative NUV − r color gradient. We do not see clear gradients of HI fraction in either the higher- or lower-mass subsample. We propose that the negative color and stellar mass gradients of galaxies can be explained by mass assembly from past galaxy mergers at different vertical filament distances. In addition, galaxy interactions might be responsible for the contrasting features of EW(Hα) and NUV − r color distributions between the higher- and lower-mass subsamples. The distributions of HI fraction of the two subsamples suggest that the processes of ram pressure stripping and gas accretion may be ignored in the Virgo filaments.

KEYWORDS Dwarf galaxies, Galaxy interactions, Galaxy evolution, Large-scale structure of the universe

Division J

#3286

New measurements of PAH dust emission as an extinction-independent star formation rate indicator from 0<z<1

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Emission complexes from polycyclic aromatic hydrocarbon (PAH) dust grains dominate the mid-infrared spectra of star-forming galaxies. They are proposed to be promising tracers of star formation in the dust-obscured universe. In this talk, I will focus on the unique advantages of using AKARI/Infrared Camera photometry in the North Ecliptic Pole (NEP) region to define effective low-resolution 9-point "spectra" from 2 --24 microns to study PAH dust emission in many hundreds of galaxies towards the epoch of peak star formation. I will describe our methodology of measuring PAH luminosities, and how we have validated it. With our large sample of new PAH measurements, I will show their correlations with optical star formation rate diagnostics, when corrected for dust extinction. I will discuss how gas-phase metallicity and AGN activity may impact observed PAH strength. Finally, I will discuss how our study relates to galaxies at higher redshifts and highlight the legacy value of our AKARI infrared data in this new and exciting era of JWST.

KEYWORDS infrared: galaxies, galaxies: active, galaxies: ISM, techniques: spectroscopic

Division J

#3277

S2TDF : Sub-millimeter galaxy survey with SCUBA-2 in JWST Time Domain Field (JWST-TDF)

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We introduce our James Clerk Maxwell Telescope (JCMT) SCUBA-2 850 um imaging observation and sub-millimeter source properties in the JWST (James Webb Space Telescope) Time-Domain Field (TDF). The JWST-TDF field is a ~ 14' diameter survey field near the North Ecliptic Pole that will be surveyed as one of the JWST Guaranteed Time Observations programs with NIRCam and NIRISS. Sub-millimeter sources correspond to strongly star-forming (SFR > 100 Msun/yr) dust-obscured populations, which have contributed to the cosmic star formation history in the early Universe. We newly found 114 (82) 850 um sources at SNR > 3.5 (> 4), with false detection rates of 8 % (1 %) in the deep SCUBA-2 map covering the entire field of JWST-TDF field. The number counts of sub-mm sources agree with previous studies at flux densities of 3-10 mJy. We performed multi-wavelength data matching from optical to radio for 67 sub-millimeter sources. We find that physical properties of the sub-mm sources are in line with bright sub-millimeter galaxies from other surveys with the median redshift of z=1.96, median star-formation rates of 240 Msun/yr, and typical cold dust masses of 4.4 x 10^8 Msun. From the large masses of cold gas mass derived from the dust mass for our sub-mm sample, we suggest that sizeable cold gas mass is one of the critical factors necessary to drive the high star-formation rates seen in this population.

KEYWORDS Galaxy Evolution, Galaxy Formation, High-redshift galaxies, Submillimeter astronomy, Galaxy counts, Ultraluminous infrared galaxies

Division J

#3239

Hyperluminous Dust-Obscured Galaxies Hosting SMBH at z~2

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It is known that several populations of high-redshift hyperluminous galaxies are undergoing intense star-formation activity at the early universe. Here we present the spectral line analysis through near-infrared (NIR) and optical spectroscopic follow-ups for Hyperluminous Dust-Obscured Galaxies (DOGs) in the AKARI Deep Field – South (ADF-S). Most of our DOG samples host massive SMBH, whose mass was measured from broad H-alpha emission lines. It seems to settle down in the MSMBH – Mgalaxy relation of local AGNs, although there are outliers. Recently, some highly obscured galaxies which show significant but unexpected blue excess emission in their SEDs are discovered. However, the origin of blue excess emission is still unclear. In this study, we report our spectroscopic study of hyperluminous DOGs including two mysterious DOGs.

KEYWORDS High-redshift galaxies, Active galaxies, Infrared-galaxies

Division J

#3226

Developing new recipes for measuring the dynamical state of galaxy clusters using simulations

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In the hierarchical formation scenario, massive structures such as clusters are the most likely to be actively assembling today, and thus can be found in a wide range of dynamical states. Using cosmological simulations (the N-cluster simulations), we derive new and improved recipes for measuring the dynamical state of observed clusters. Using multiple 3D dynamical indicators, we find the best combinations to detect mergers at recent or ancient times since the merger. We also convert these recipes into projected versions that can be applied directly to observations. In this poster, we will present our methodology and demonstrate our results.

KEYWORDS Galaxy cluster, dynamical state

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#3215

Spiral Graph: Pitch Angle Measurements of Spiral Galaxies from Data Collected by Citizen Scientists

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Spiral Graph is a citizen science project developed on the Zooniverse platform in order to help determine the spiral arm pitch angle (ϕ) of galaxies. g-band images, taken primarily from DECaLS DR8 or secondarily from SDSS, of the stellar mass-complete sample of 6222 spiral galaxies from Hart et al. (2017) were deprojected, uploaded, and presented to volunteers. The volunteers were first asked to confirm that the object centered in the image is indeed a non-interacting spiral galaxy. If confirmed, they were then tasked with tracing over the visible arms, ignoring the bulge and any bar, ring, or foreground star. The resultant tracings from at least 15 different volunteers were aggregated and input into P2DFFT, an algorithm used to measure ϕ. We compare the results of this pitch angle measurement process (ϕ_{SG}) to other methods including those determined by SpArcFiRe (ϕ_{SF}; as reported by Hart et al. 2017), Spirality (ϕ_{SY}), and manually overlaying logarithmic spirals of known pitch angle (ϕ_{OL}). We find that ϕ_{SG} most strongly correlates with $\phi_{\cancel{OL}}$ and correlates least with ϕ_{SY}.

KEYWORDS galaxies, spiral, citizen science, pitch angle, extragalactic, community science

Division J

#3079

Density of Lyman Alpha Emitter Galaxies at z = 6

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In this work, we study the number density of Lyman Alpha Emitter (LAE) galaxies, their physical properties, and synthetic spectra at redshift ~ 6 using high-resolution hydrodynamical simulations with radiative transfer from the Thesan project. By recreating the scenario described in Becker et al. 2018, we test the hypothesis that observations to date are missing the vast majority of the high-redshift galaxies' signals since they are extremely faint and, thus, are out of the observational limits of our current telescopes. We also follow the evolution of the neutral Hydrogen fraction, the chemical enrichment of the circum- and intergalactic medium, and the specific star formation rate of galaxies in the simulation at the end of Reionization, and evaluate why the detections from HST and the Silverrush project significantly underestimate the number of faint galaxies. Our study indicates an observational bias to massive galaxies in the field. Thus, we forecast the properties of the dwarf galaxies responsible for completing the budget of ionizing photons that concluded the Epoch of Reionization.

KEYWORDS LAE, Galaxies, Reionization, IGM

Division J

#3025

Study of the physical properties of the accretion disk in AGNs, based on light curve analysis

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The active nucleus present in some galaxies is characterized fundamentally by variability in the emissions on different spectrum ranges. To study the properties of the variability of light curves, CARMA model was applied to the present work, based on analytical development and computational models, over a database of 100 quasars, taken from the DR7 repository of the Sloan Digital Sky Survey (SDSS), on their 5 ugriz bands. In this process, carmapack was used, developed on the python programming language, getting statistical parameters that describe the light curves. Also were searched on the literature and databases the light emission on $L_{\lambda}(5100\textup{\r{A}})$, $L_{\lambda}(3000\textup{\r{A}})$,$L_{\lambda}(UV 3300\textup{\r{A}})$, $L_{\lambda}(H_{\beta} 4861\textup{\r{A}})$, $L_{\lambda}(MG II)$, $L_{\lambda}[{O II}] (5007\textup{\r{A}})$, $L_{\lambda}[{O III}](4959\textup{\r{A}})$ of the study objects, and correlation was evaluated with the statistical parameters of the CARMA model. It was found that there's a high correlation between the statistical parameters of the CARMA model. Still, nevertheless, there's no correlation between the statistical parameters of the model and the light emission. Finally, it was made a classification of the process: stationary stochastic and nonstationary stochastic of the results on the CARMA predictive model. Generally, we can conclude that on the near-infrared band z there's a better prediction of the photometry under this model, with a stationary stochastic process.

KEYWORDS AGNs, light curve, variability, CARMA(p,q)

Division J

#3015

The BAT AGN Spectroscopic Survey Data Release 2: Spectroscopic Line Measurements and AGN Demographics

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We present the second catalog and data release of optical spectral line measurements and AGN demographics of the BAT AGN Spectroscopic Survey, which focuses on the Swift-BAT hard X-ray detected AGNs. We use spectra from dedicated campaigns and publicly available archives to investigate various spectral properties of most of the AGNs listed in the 70-month Swift-BAT all-sky catalog; specifically, 743 of the 746 unbeamed and unlensed AGNs (99.6%). We find a good correspondence between the optical emission line widths and the hydrogen column density distributions using the X-ray spectra, with a clear dichotomy of AGN types. Based on optical emission-line diagnostics, we show that 48%–75% of BAT AGNs are classified as Seyfert, depending on the choice of emission lines used in the diagnostics. The fraction of objects with upper limits on line emission varies from 6% to 20%. Roughly 4% of the BAT AGNs have lines too weak to be placed on the most commonly used diagnostic diagram, [OIII]λ5007/Hβ versus [NII]λ6584/Hα, despite the high signal-to-noise ratio (S/N) of their spectra. This value increases to 35% in the [OIII]λ5007/[OII]λ3727 diagram, owing to difficulties in line detection. Compared to optically-selected narrow-line AGNs in the Sloan Digital Sky Survey, the BAT narrow-line AGNs have a higher rate of reddening/extinction, with Hα/Hβ > 5 (~ 36%), indicating that hard X-ray selection more effectively detects obscured AGNs from the underlying AGN population. Finally, we present a subpopulation of AGNs that feature complex broad-lines (34%, 250/743) or double-peaked narrow emission lines (2%, 17/743).

KEYWORDS Active Galactic Nuclei, demographics, optical emission-line measurements, data release

Division J

#2974

Cosmological QUOKKAS
- A new method for measuring cosmological distances

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Recently there has been substantial debate around the reliability of cosmological distance measures. Potential sources of systematic error could be influencing the interpretation of results. For this reason, there is a great need for a new and independent distance measure. In this presentation, I will present the 'standard speed-gun' method of measuring distances to blazars which can be seen from $0 < z < 6$. The core assumption of the method is that the variability seen in blazars is constrained by the speed of light. This then allows us to calibrate a standard ruler, that is then compared with the apparent size; measured with VLBI. We applied this method to the famous nearby source 3C 84 and derived a measurement of the Hubble Constant. This technique has several advantages over other distance measures such as Type Ia supernovae but is currently limited by the sensitivity of existing VLBI arrays. New arrays such as SKA-VLBI and the ngVLA could potentially, allow distance measurements to tens of thousands of sources or more.

KEYWORDS cosmology, VLBI, AGN

Division J

#2965

Probing missing baryons with thermal and kinematic Sunyaev-Zeldovich effect

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Previous studies of galaxy formation have shown that only 10 percent of the cosmic baryons are in stars and galaxies, while 90 percent of them are missing. In this talk, I will present three observational studies that coherently find significant evidence of the missing baryons. The first is the cross-correlation between the kinetic Sunyaev-Zeldovich maps from Planck with the linear reconstructed velocity field. We find significant (4.6 sigma) detection of the peculiar motion of gas on Mpc scales, for which we can reconstruct the baryon fraction. The second study is the cross-correlation between the thermal Sunyaev- Zeldovich effect with gravitational lensing map and we detect the cross-correlation for 13 sigma with RCSLenS and Planck data. The third study is to stack the pairs of luminous red galaxies and subtract the halo contribution, which leads to the detection of gas within filaments. I will discuss the implication of these results toward understanding the temperature and density of the warm-hot baryons.

KEYWORDS IGM, missing baryon, CGM, feedback, ionised baryons, neutral baryons

Division J

#2944

Probing the Early History of Cosmic Reionization by Cosmic-Varince Limited CMB Experiments

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From the epoch of recombination when the universe first became transparent, the thermal radiation traveled almost freely to be observed as the cosmic microwave background (CMB). However, stellar objects gradually ionized the atoms in the Universe to produce free electrons (a process called cosmic reionization), which then act as optical obstacles to cause the scattering of the thermal radiation. Understanding how the CMB got affected by these free electrons opens up a possibility to probe how cosmological and astrophysical processes proceeded in the early universe. We show that the very early phase of cosmics reionization, at redshifts z>15, can be probed by future, cosmic-variance limited CMB experiments such as LiteBIRD. We review the currents constraints on cosmic reionization and how such a future probe may detect the first-star formation activity inside "minihalos", if nature had hosted non-negligible star formation at z>15 inside these small halos.

KEYWORDS cosmic reionization, cosmic microwave background, first star, LiteBIRD

Division J

#2861

Gravitationally bound systems at low acceleration limit - from dwarf galaxies to smaller systems

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In this research we investigated the deviations from Newtonian dynamics in astronomical systems from dwarf galaxies to asteroid-like objects. For these cases the influence of dark matter is not so important in comparison with the case of galaxy clusters, giant and normal galaxies where the dark matter and deviations from Newtonian dynamics can work together.

That is why the observed deviations can be used to find the possible modification of Newtonian law, like MOND. Note that MOND was initially proposed for explanation of observed phenomena in giant and normal galaxies. We analyzed the published catalogues of lower scale objects and tryed to find the possible limitations for the use of Newtonian dynamics.

The most reliable results were obtained for globular clusters and dwarf galaxies.

KEYWORDS Gravitation, dwarf galaxies, globular clusters, MOND

Division J

#2692

Stellar Mass in Bars:
Infrared Insights from the Local Universe

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Stellar bars are present in ~2/3 of nearby spirals and play a critical role in the evolution of their hosts. We exploit the Spitzer Survey of Stellar Structure in Galaxies (S4G) database to study the deepest mid-infrared imaging available for ~350 massive bars in the 3.6um and 4.5um IRAC/Spitzer bands. Based on the 2D decomposition of these images with the multi-band galaxy structure decomposition tool GALFITM, we translate stellar light to stellar mass associated to the primary bar in these systems. Considering that the mid-infrared represents the best single-band tracer of stellar mass in galactic structures, we use these results in an effort to provide a broad understanding of the stellar mass content typically contained in these ubiquitous structures. Preliminary results point to bars encompassing from a few percent to 30% of the galaxy's total stellar mass, with a typical value of 7%. We are initiating a similar study based on Illustris/TNG-50 simulations to compare the mass distributions of these structures as produced in state-of-the-art cosmological simulations.

KEYWORDS bars, mid-infrared, 2D decomposition, stellar mass, observations, simulations

Division J

#2548

The HI properties of the local X-ray AGN host galaxies

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We present the neutral hydrogen (HI) gas properties of ~ 15 nearby (z<0.0275) X-ray AGN host galaxies. Our local X-ray AGNs are selected based on the BAT AGN Spectroscopic Survey (BASS), hard X-ray all-sky observation combined with the optical spectroscopic data. In this work, we describe the details of the HI morphology, kinematics, and content of our local X-ray AGN host galaxies. The goal is to establish the dynamic state of the cold gas reservoir of AGN host galaxies. Furthermore, to study the impact of AGN activity on the star formation process, we investigate the location of X-ray AGN host galaxies on the known relation of radio continuum and far-infrared emission. We probe whether the AGN sample follows the same radio-FIR relation of normal star-forming galaxies, and if not, how cool gas properties are responsible for their offset from this relation, and hence star formation activities.

KEYWORDS neutral hydrogen, X-ray AGN, radio continuum

Division J

#1186

Star Formation and Chemical Enrichment in Protoclusters

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Protoclusters (PCs) are the densest regions in the early universe, and many candidates of PCs have recently been discovered. At high redshift universe, star formation (SF) in high-density regions is more active than that in low-density environments. The galaxies in PCs grow to massive elliptical galaxies with quenched SF, as seen in current galaxy clusters. Therefore, PCs are important for the understanding of the evolution of galaxies and the cosmic SF history in the universe despite the low PCs number density.

Due to the deep gravitational potential of the PCs, heavy elements released from stars are stored in the intra-cluster medium. The chemical abundance of PCs reflects its SF history and the feedback activities in the galaxies.

We study the PCs' star formation, gas metallicity, and chemical evolution at z~0-10 using the cosmological smoothed particle hydrodynamics code GADGET3-Osaka. Using the chemical evolution library CELib, we compute the metal release rate from stellar particles by type II supernovae (SNII), type Ia supernovae (SNIa), and AGB stars.

The total star formation rate (SFR) in our most massive PC (>1015 h-1M$_\odot$) reaches >104 M$_\odot$ yr-1 at z=3, equivalent to observed PCs. The SFR in the core accounts for <30% of the total SFR in the PC at z>1, suggesting the importance of the outer regions to reveal the evolution of the galaxy clusters. By examining the chemical evolution on the [O/Fe] vs. [Fe/H] diagram, we show that the decline of SFR changes the track on it. This is because the metal enrichment by SNII and SNIa, which occurred during active SF, becomes SNIa-dominated, when SF begins to be suppressed, and iron is in excess relative to oxygen. We also discuss the evolution of PCs with different masses and different feedback models.

KEYWORDS galaxy formation, protoclusters, chemical evolution, galaxy cluster, simulaiton

Division J

#2297

Neon and [CII] 158μm emission line profiles in dusty starbursts and AGN

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A sample of 379 extragalactic sources is presented that has mid-infrared, high-resolution spectroscopy from the Spitzer Infrared Spectrograph (IRS) and also spectroscopy of the [CII] 158μm line from the Herschel Photodetector Array Camera and Spectrometer (PACS). The emission line profiles of [NeII] 12.81μm, [NeIII] 15.55μm, and [CII] 158μm are presented, and intrinsic line widths are determined (full width half maximum of Gaussian profiles after instrumental correction). All line profiles, together with overlays comparing the positions of PACS and IRS observations, are made available in the Cornell Atlas of Spitzer IRS Sources. Sources are classified from active galactic nucleus (AGN) to starburst based on equivalent widths of the 6.2μm polycyclic aromatic hydrocarbon feature. It is found that intrinsic line widths do not change among classifications for [CII], with median widths of 207km/s for AGNs, 248km/s for composites, and 233km/s for starbursts. The [NeII] line widths also do not change with classification, but [NeIII] lines are progressively broader from starburst to AGN. A few objects with unusually broad lines or unusual redshift differences in any feature are identified.

KEYWORDS Infrared, galaxies, active galaxies, starburst, distances, redshift

Division J

#2292

Analysis of Emission Line Widths of [CII] 158μm

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A study of [CII]158μm emission line profiles observed with Herschel PACS for 379 galaxies is presented. Emission line widths are compared to [CII] luminosities, to near-infrared 1.6μm luminosities and to infrared 22μm luminosities to decide if any luminosity relates to velocity dispersion.

Archival data for [CII] fluxes and line profiles are taken from http://cassis.sirtf.com/herschel/. Line profiles are classified as Gaussian, flattened and asymmetric based on the comparison of observed profiles to Gaussian fits. Profile shapes can indicate the origin of the line widths because the lines whose width is caused by three dimensional random motions in a galaxy should be Gaussian, but widths caused by rotation of a disk should not be Gaussian. H magnitudes are taken from 2MASS catalogues, and 22μm fluxes from the WISE catalogue.

KEYWORDS Infrared, galaxies, starburst, active galaxies, distances, redshifts

Division J

#2153

Cannibalism Caught in the Act – on the Frequency of Occurrence of Multiple Cores in Brightest Cluster Galaxies

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Although it is generally accepted that massive galaxies form in a two-phased fashion, beginning with a rapid mass buildup through intense starburst activities, followed by primarily dry mergers that mainly deposit stellar mass at outskirts, the late time stellar mass growth of brightest cluster galaxies (BCGs), the most massive galaxies in the universe, is still not well understood. Several independent measurements have indicated a slower mass growth rate than predictions from theoretical models. We attempt to resolve the discrepancy by measuring the frequency of BCGs with multiple-cores, which serve as a proxy of the merger rates in the central region and facilitate a more direct comparison with theoretical predictions. Using 79 BCGs at $z = 0.06$-0.15 with integral field spectroscopic (IFS) data from the MaNGA survey, we obtain a multiple-core fraction of 0.11 ± 0.04 at $z \approx 0.1$ within a 18 kpc radius from the center, which is comparable to the value of 0.08 ± 0.04 derived from mock observations of 218 simulated BCGs from the cosmological hydrodynamical simulation IllustrisTNG. We find that most of cores that appear close to the BCGs from imaging data turn out to be physically associated systems. Anchoring on the similarity in the multiple-core frequency between the MaNGA and IllustrisTNG, we discuss the mass growth rate of BCGs over the past 4.5 Gyr.

KEYWORDS galaxy clusters, brightest cluster galaxy, galaxy formation, galaxy merger

Division J

#2151

A Pair of Early- and Late-Forming Galaxy Cluster Samples: Implications for Detection of Halo Assembly Bias

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The halo assembly bias, a phenomenon referring to dependencies of the large-scale bias of a dark matter halo other than its mass, is a fundamental property of our standard cosmological model. First discovered in 2005 via high-resolution numerical simulations, it has been proven very difficult to be detected observationally, with only a few convincing claims of detection thus far. The main obstacle lies in finding an accurate proxy of the halo formation time. In this study, by utilizing a constrained simulation that can faithfully reproduce the observed structures larger than ~2 Mpc in the local universe, for a sample of about 630 massive clusters at $z \leq 0.12$, we find their counterpart halos in the simulation and use the mass growth history of the matched halos to estimate the formation time of the observed clusters. This allows us to construct a pair of early- and late-forming clusters, with similar mass as measured via weak gravitational lensing, and large-scale bias differing at $\geq 4\sigma$ level, clearly showing the signature of assembly bias.

KEYWORDS large-scale structure of Universe, cosmology, galaxy cluster, structure formation

Division J

#2051

Retrieving cosmological information from clusters and hot diffuse gas in CMB small scales

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Planck experiments have observed galaxy clusters using their SZ signature but was also able to produce maps of the full hot gaz distibution in the sky (including clusters and more diffuse components). The SPT data at very small scales are known to probe not only primordial CMB fluctuations but also many extragalactic components such as tSZ, kSZ, CIB, points sources.

I will show how to use the cosmological dependent SZ signature at small scales coherently with the large scales and the cosmology framework in these two experiments to retrieve both cosmological parameters and cluster scaling relations. Using machine learning to compute efficiently the SZ angular power spectrum, I will show new constraints obtained using SPT CMB observations combined with the latest Planck observed tSZ spectrum and compare them with constraints obtained with cluster number counts. I will discuss how such a coherent analysis could bring additional cosmological information and shed light on the sigma8 tension observed between CMB and clusters.

KEYWORDS hot gas, cosmology

Division J
#2041

On the Study of Binary Black Holes System and Long-term Periodicity Analysis

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Variability is the typical observational property for blazars, which sheds some light on the nature and emission properties of blazars. Based on the observations, the variations have been found to have different timescales and divided into intraday variability (IDV) with the timescales, TVar being a few minutes to 1 day, short-term variations with TVar being a few days to months, and long-term variations (LTVs) with TVar being years. In this poster, we will report our recent study on optical photometry and monitoring of two blazars, 3C 454.3 and 1ES 2344+514, and quasi-periodic oscillation in γ-ray emission from the FSRQ S5 1044+71 (Fan et al., 2021, ApJS, 253, 10; Cai et al., 2021, ApJS, Accepted; Wang et al., 2021, ApJ, in press).

Utilizing the observational data from the 70 cm meniscus telescope at Abastumani Observatory in Georgia, we obtain 8523 pairs of R-band optical photometry observations for the quasar 3C 454.3 made during the period of 2006 October–2018 February and carried out in the period of July 1998 - November 2017 for 1ES 2344+514, respectively. Firstly, for 3C 454.3, (1) we detected 10 outbursts, a ΔR = 3.825 mag variation, and some IDVs; (2) The IDV timescales suggest that the emission sizes are from 8.9 × 1013 cm to 6.20 × 1015 cm, and the magnetic field strengths are B=0.18–0.79 G; (3) Period analysis results show three possible long-term periods, p=3.04±0.02yr, p = 1.66 ± 0.06 yr, and p = 1.20 ± 0.03 yr in the optical light curve.

For 1ES 2344+514, we ascertain: (1) A variability of ΔR = 0.155 mag (15.356 – 15.201 mag) over a timescale of ΔT = 12.99 minutes was detected during our 628 days of monitoring; (2) A promising period is P = 2.72±0.47 yr. When we consider a binary black hole system, we obtained the orbital parameters for the binary black holes system: M = 8.08 × 109M⊙; the sum of semiaxes is r = 7.18 × 1016 cm; the lifetime of is τmerge = 6.24 × 102 yr. We also probe the relationship between the period and gravitational wave energy when the binary black holes merge.

Finally, we performed several methods for the γ-ray light curve study of the FSRQ S5 1044+71 covering an observational period of ~ 9 yr (from MJD 56013 to 59298), a quasi-periodic oscillation (QPO) with a period of ~ 3.06 ± 0.43 yr is found at the significance level of ~ 3.6σ. Thus we propose that a binary black hole model can be used to explain this possible quasi-periodic variability.

KEYWORDS Active galactic nuclei, CCD photometry, gamma rays, quasars, black hole

Division J

#1915

NGC4622's Unusual Rising Outer Disk Surface Density calculated from Its Rotation Curve and Leading Outer Arms

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NGC4622 was initially thought have a beautiful outer pair of trailing "textbook" density wave arms outlined by stellar associations (Shu 1982). Later Byrd et al (2008 and references) discovered that the outer pair actually leads along with a new single trailing inner arm. We show here that NGC4622 has a textbook density wave displacement of stellar associations relative to stellar arms, except at co-rotation of the arm pattern with the rotation curve. We use NGC4622's unusual flat then rising rotation curve, its co-rotation radii, and arm pitch to calculate the surface mass density of the disk versus radius. The surface density is comparable to that in our Milky Way out to ~5 kpc then it rises to much larger values at 8 kpc radius. So, NGC 4622 is an extremely unusual galaxy with not only a beautiful leading outer pair of "density wave" arms but an outer disk of increasing surface density with radius.

See https://www.researchgate.net/profile/Gene-Byrd/research "NGC4622: Unusual Spiral Density Waves and Calculated Disk Surface Density"

KEYWORDS NGC4622, spiral arms, leading spiral arms, rising rotation curve, rising surface density, density wave

Division J

#1875

A Panoramic View of the Intracluster Globular Cluster System in Hydra

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The Hydra Cluster, also known as Abell 1060, is one of the largest and nearest rich cluster of galaxies in the local universe and hosts a massive globular cluster system. As such, we expect the existence of a population of Intracluster Globular Clusters (IGCs) as found in other nearby massive clusters. IGCs are a population of GCs bound to a galaxy cluster rather than to individual galaxies. They are important to understand because they provide valuable insights into the hierarchical assembly history of galaxy clusters. Therefore, we use Hyper Suprime-Cam (HSC) archival images to study a panoramic view of the Hydra cluster, spatially complete past its virial radius and covering up to 1.8 degrees from the cluster center. From this, we obtain the largest survey of globular clusters in Abell 1060. We select IGC candidates as those with colors similar to galaxy globular cluster colors but at distances outside of regions dominated by galaxy potential. We find that there exists a large population of intracluster globular clusters that is not associated with any individual galaxy and outside of the region dominated by the central cD galaxy NGC 3311. We investigate this IGC population and study its distribution, extent, and relation with the different galaxy populations in Hydra. We discuss the origin of the IGC population in Hydra and provide comparison with those found in other nearby massive clusters. Thus, we present the most comprehensive study of the intracluster globular cluster system in Hydra.

KEYWORDS globular clusters, intracluster globular clusters, stellar populations, galaxy formation, hydra cluster, abell 1060, NGC 3311

Division J

#1525

A New Method to Reconstruct Cluster Merger Scenarios with Multi-wavelength Data

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Merging clusters are useful tools to study cosmic ray acceleration and dark matter. Thus they are studied in various ways including weak-lensing, X-ray, radio observations. However, It is difficult to infer the merging scenario of clusters with those observation data alone. We propose a method to reconstruct the merger scenario by comparing a suite of numerical simulations with those multi-wavelength observations and obtain the posteriors of the merger parameters with the method. The strength of our method is that since it is based on numerical simulations, it can include the dynamic friction, asymmetric acceleration, and shock propagation that the pure analytic approach cannot implement. We applied our method to ACT-CL J0102-4915 (El Gordo) to obtain merger scenarios and posteriors of merger parameters, and find that it agrees well with multi-wavelength data while it leads to some differences with the previous studies. Finally, we demonstrate that this method can be easily applied to other cases with different dark matter properties.

KEYWORDS galaxies: clusters, methods: numerical, method: statistical, dark matter, cosmology

Division J
#1399

Some S type galaxies' spiral arm disks dominate over their halos

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We find that, despite having flat rotation curves, V, some S type galaxies are disk-dominated with little halo over their disk spiral arm regions. In other galaxies, halos dominate. Relaxation stabilizes the local velocity dispersion relation so that two-fold arms dominate. We derive how arm steepness and V give the disk surface mass density as a function of radius and the relative importance of the halo and disk. We demonstrate this analytic relation's validity via disk galaxy simulations. Examples are: the disk dominated NGC 3198, intermediate M101 and M51 and halo dominated NGC7217. Interestingly smaller arm pitches in S galaxies correlate with more massive central black holes.

See https://www.researchgate.net/profile/Gene-Byrd/research "Spiral Galaxies When Disks Dominate their Halos (using Arm Pitches and Rotation Curves)".

KEYWORDS S type galaxies, spiral arms, dark matter halo, flat rotation curves, halo versus disk, NGC7217, NGC3198

Division J

#1111

A missing black hole population of optically invisible X-ray sources in the early Universe

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The recent discovery of a significant cross-correlation signal between the residual cosmic X-ray and infrared backgrounds points towards the possibility of a yet undiscovered population of heavily obscured black holes in the early universe. Here we present the newly discovered 62 optically invisible X-ray sources (i.e., without any optical/NIR counterparts) in the COSMOS field, ~40% of which are detected in ALMA band 7 FIR continuum observations. For those ALMA-detected sources, we find that they are most likely heavily obscured AGNs at z=3-5, or even at higher redshift. JWST Cycle 1 observations are scheduled for some of these targets to identify the nature of these sources, which is critical not only to start exploring the heavily obscured population at high redshift but also to provide valuable observational constraints on a hidden phase of a significant growth of supermassive black holes in the early universe.

KEYWORDS Black hole physics, X-rays: galaxies, Galaxies: active, Galaxies: high-redshift

Division J

#1013

A Novel Analysis of Contamination in Photometric Samples at High Redshift: Spatial Correlation with Lower Redshift Galaxies

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The intergalactic matter in the universe undergoes a phase transition from neutral to ionized state in the first billion years, termed as "cosmic reionization". Lyman-break galaxies (LBG) are the leading candidate sources for producing the necessary ionizing radiation. Unfortunately, photometric selections of high-redshift LBGs are potentially subject to contamination from low/intermediate redshift galaxies with a prominent 4000Å Balmer break that may have observer-frame spectral energy distributions mimicking a Lyman-break. To investigate in a novel way the impact of contamination, we study the spatial correlation between intermediate ($z \sim 1.3$ - 2) and high redshift ($z \sim 6$ - 8) galaxies in Hubble Space Telescope large-area surveys and link it to the leakage fraction. We compare the observed correlations for various Hubble Space Telescope surveys to outcomes from Monte Carlo simulations of leakage. Our results indicate that while ultradeep observations in the Hubble eXtreme Deep Field appear to have negligible contamination, larger area surveys such as the CANDELS GOODS-S and BoRG might have underestimated the purity of photometric samples.

KEYWORDS cosmology: observations, galaxies: high-redshift

Division J

#935

The first model-independent measurement of potential decay rate from observation

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We isolate the decay rate (DR) of gravitational potential from observation by measuring the ratio of the ISW-large-scale structure (LSS) cross-correlation and lensing-LSS cross-correlation. The resultant DR enables us to make constraints on a flat wCDM universe in a model-independent way. In this work, we use 'low-density point' (LDP) for the LSS tracer for investigating the cross-correlation with Planck cosmic microwave background (CMB) products, for which LDPs are constructed with about 3\times10^6 galaxies from the DR8 galaxy catalogue of DESI survey. It provides a subtle way to measure DR from low-density regions of the universe. We perform the analysis mainly on two independent redshift slices: 0.2<z<0.4 and 0.4<z<0.6, and get non-zero detections of DR with a total significance of 3.1sigma. Together with the baryon acoustic oscillation (BAO) data, we make constraint on a flat wCDM model. We also use galaxies for consistency check and get similar results.

KEYWORDS gravitational potential, cosmic background radiation, gravitational lensing, large-scale structure of Universe

Division J

#933

Cosmological Constraints from an Improved Alcock–Paczynski Test Method with the SDSS Data

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We apply the improved Alcock-Paczyski (AP) test method to SDSS data, using the redsfhit-space two-point correlation function (2PCF). We derive cosmological constraint by examining the redshift dependence of the shape of 2PCF as an incorrect choice of the cosmological model could introduce geometric distortion. In this work, we do the analysis based on the SDSS DR7 sample, BOSS DR12 samples and the LRG sample of the eBOSS DR16 data release. We split the galaxy samples into seven redshift bins for performing 2PCF statistics, and employee a set of high resolution Nbody simulations for correcting the nonlinear evolution in the 2PCF. At last, we obtain a robust constraint on a flat wCDM model.

KEYWORDS Alcock-Paczyski, Two point correlation function, dark energy

Division J

#482

Multiwavelength dissection of a massive heavily dust-obscured galaxy and its blue companion at z~2

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We study a system of two galaxies, Astarte and Adonis, at z ~ 2. At this time, the Universe was undergoing the peak of its star formation activity. Astarte is a dusty star-forming galaxy at the massive end of the main sequence (MS), and Adonis is a less massive companion galaxy that is bright in the ultraviolet and has an optical spectroscopic redshift. We investigate whether this ultramassive galaxy is quenching, and whether it has always been on the MS of star-forming galaxies.

We used the code CIGALE to model the spectral energy distribution. The code relies on the energetic balance between the ultraviolet and the infrared. We derived some of the key physical properties of Astarte and Adonis, mainly their star formation rates (SFRs), stellar masses, and dust luminosities. We inspected the variation of the physical parameters depending on the assumed dust-attenuation law. We also estimated the molecular gas mass of Astarte from its CO emission, using different αCO and transition ratios (r31), and we discuss the implication of the various assumptions on the gas-mass derivation.

We find that Astarte exhibits a MS-like star formation activity, and Adonis is undergoing a strong starburst phase. The molecular gas mass of Astarte is far lower than the gas fraction of typical star-forming galaxies at z = 2. This low gas content and high SFR result in a depletion time of 0.22 ± 0.07 Gyr, which is slightly shorter than expected for a MS galaxy at this redshift. The CO luminosity relative to the total infrared luminosity suggests a MS-like activity when we assume a galactic conversion factor and a low transition ratio. The SFR of Astarte is on the same order when different attenuation laws are used, unlike its stellar mass, which increases when shallow attenuation laws are used (~1 × 1011 M⊙ assuming a Calzetti relation, versus ~4 × 1011 M⊙ assuming a shallow attenuation law). We discuss these properties and suggest that Astarte might be experiencing a recent decrease in star formation activity and is quenching through the MS following a starburst epoch.

KEYWORDS dust attenuation, high-redshift, ISM, ALMA, starburst galaxies

Division J

#484

Decoding the IRX-β dust attenuation relation in star forming galaxies at intermediate redshift

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In galaxies, different components interact with each other on various timescales. An example of such interaction is the interplay between young and as well evolved stars with dust. This complex interplay influences the total spectra of galaxies. Dust affects the shape of the spectral energy distribution (SED) like no other component, despite its low contribution to the overall mass of the baryonic matter.

At higher redshifts, the challenging measurements of FIR emission are overpowered by the easily available rest-frame UV emission. This in turn limits the wavelength range from which the physical properties are inferred, therefore, a correct understanding of physical processes that prevail at short wavelength domain, like dust attenuation, becomes critical.

Observationally, many galaxies seem to follow what is known as the IRX-β relation, which links heavily-attenuated UV spectral slope (β) and the IR excess of galaxies characterised by the ratio between the IR (mainly dust) and UV (mostly composed of young stars) luminosities (L(FIR)/L(UV)). However, this relation is not universal, and outliers for it are often encountered.

Understanding such relation and its connection to dust attenuation properties will help us uncover and understand the role of dust, and its attenuation at higher redshifts.

Our study used a unique dataset from the "VIMOS Public Extragalactic Redshift Survey" (VIPERS), which mapped in detail 24 deg2 of the sky sampling galaxies at redshift~0.7. We use the robust Oii, Oiii, and Hβ line detections of our statistical sample from VIPERS to estimate the gas-phase metallicities at the redshift range 0.5 z 0.9. We derive key physical properties that are necessary to study galaxy evolution, such as the stellar masses and the star formation rates, from the SED fitting tool CIGALE.

We find a strong dependence of the IRX-β relation on gas-phase metallicity in our sample and dependencies on stellar properties of galaxies like stellar ages, stellar masses, and specific star formation rates. We have also checked morphological parameters, and we find that the compactness of our sources characterised by the Sérsic indexes is also sensitive to the location on the IRX-β plane.

KEYWORDS dust attenuation, high-redshift, ISM, Main sequence, gas-phase metallicity

Division J

#483

Dust attenuation in ALMA-detected Ultra Dusty Star-Forming galaxies up to z = 4

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Despite its low contribution to the total mass of the interstellar medium (ISM), dust plays a crucial role in the evolution of galaxies, and it has the biggest impact on the spectral energy distribution. The affluence of infrared and radio detections of millions of galaxies in the COSMOS field, provided by powerful instruments such as Herschel and ALMA, has allowed us to study the cold dust in galaxies and its variation over a wide range of redshift.

The key to reproduce the total spectral energy distributions of galaxies is the assumption of a dust attenuation law which accounts for the behaviour and the imprints of the dust. However, different studies have shown that a single law cannot fully model dust in a large sample of galaxies. This non-universality of attenuation laws should be considered in order to accurately account for dust, and therefore in determining the physical properties of galaxies. In this work, we study different attenuation laws in a large sample of ALMA-detected galaxies in the COSMOS field. We probe the resulting variation of the

key physical properties of these galaxies such as the star formation rate, the stellar mass and the dust to stellar mass ratio. We also investigate the dust temperatures in the ISM and spatial extent of the dust continuum and the implication that it might have on the attenuation curve. We find that various attenuation curves must be used in order to reproduce the UV spectrum. Although these curves are not redshift-dependent, they are correlated to the relative spatial distribution to the stellar population of the heavily dust-obscured galaxies.

KEYWORDS dust attenuation, high-redshift, ISM, ALMA, starburst galaxies

Division J

#457

Primordial Black Holes and Gravitational Waves

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With the discovery of gravitational waves from merging pairs of massive black holes, the interest in the question of whether Primordial Black Holes (PBHs) could constitute the Dark Matter (DM) has recently been revived. In this talk, I will review the different mechanisms for (DM) PBHs formation with a special focus on the excursion set theory. I will also explain the hierarchical merger of PBHs in dwarf galaxies which can explain the mass gap and mass asymmetry in the detected events of LIGO/Virgo.

KEYWORDS Gravitational Waves, Dark Matter, Primordial Black Holes

Division J

#311

Measurement of star formation rate densities across the cosmic time

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We present the star formation properties of ~2000 sources detected in the Spitzer and the Herschel 70 micron and 160 micron observations. Analyzing the star formation rates (SFRs) of these galaxies provides the distribution of SFRs across the redshift range, $0 < z < 6$. We also investigate the star formation rate densities (SFRDs) based on the present analysis of SFRs with FIR luminosity and comoving volume calculated from the selected cosmic parameters.

KEYWORDS Star Formation Rate, Star Formation Rate Densities, Comoving Volume, Cosmic Parameters

Division J

#304

A Detailed Morphological and Spectroscopic Study of Merging Blue Compact Dwarf Galaxies

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We present a detailed morphology and spectroscopic study of a sample merging dwarf galaxies to explore the possible formation of the blue compact dwarf galaxy (BCD) through the merger. Using the publicly available spectroscopic data from the Sloan Digital Sky Survey (SDSS), we analyzed several emission lines of these galaxies. We find that the observed emission lines are well fitted with a Gaussian profile from which measured the emission line fluxes. We derived the Balmer decrement from the line ratio between Hα and Hβ which is slightly higher than the theoretical value of 2.86, suggesting a presence of the low amount of dust at the center of the galaxies and causing an internal reddening E(B – V) of range 0.035 mag to 0.958 mag. Using extinction corrected emission line fluxes, we derived the star-formation rate and emission line metallicity of the galaxies. SFR derived from Hα emission line flux is in the range of 0.0033 to 0.1176 $M_\odot$year-1 and emission line metallicity, 12 + log(O/H) derived from flux ratio between NII and Hα is in the range of 8.44 to 9.90 dex. Using the SDSS, g-band imaging data, we analyzed the structural properties of these galaxies. We find that the observed one-dimensional light profile is well fitted with a Sersic function with an index of near to one, suggesting an exponential light profile. The derived value of half-light radius from the Petrosian method is in the range of 200 to 500 parsecs, suggesting these galaxies are significantly compact compared to typical star-forming disk galaxies of similar mass.

KEYWORDS Galaxy Merger, Hα line, Star Formation Rate, Metallicity, Half-light Radius

Division J

#288

A search for a secular variation of the gravitational constant using strong gravitational fields

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Searching for varying dimensionless physical constants presents a meaningful characteristic in experimental and observational studies. One of the most valuable explorations of these variations could depend on the evolution of white dwarf stars.Applying the spectrum of white dwarf star: G191-B2B, we derive a robust limit on the cosmological variation of the gravitational constant GG=(0.238 ±2.959)×10-15 yr-1. This limit proposes a potential test of the framework of modern unification theories.

KEYWORDS varying fundamental physical constants, varying gravitational constant, white-dwarf stars spectra, absorption spectra analysis, Grand Unification Theories

e-Talks

Division J

#1674

Verifying the ΛCDM paradigm and constructing the mass scaling relation with weak gravitational lensing study of high-redshift galaxy clusters

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As the largest gravitationally bound systems, clusters of galaxies play an essential role in understanding the formation and evolution of the large-scale structure of the universe. Especially, precise and accurate mass measurements of galaxy clusters at high-z are required to verify the current ΛCDM cosmology, given that the mass function of the high-z cluster is sensitive to cosmological parameters.

In this PhD thesis research, we determine the masses of about 40 high-z galaxy clusters ($0.8 < z < 1.8$) using weak-lensing (WL) analysis. The WL analysis provides the most accurate mass estimates for these dynamically young systems because WL does not use any dynamical assumption. We use archival deep optical and near-infrared imaging data observed by the Hubble Space Telescope, which enables us to detect faint, distant source galaxies that are lensed by the foreground high-z galaxy clusters. One of our strengths is measuring the mass and concentration parameters simultaneously using the Markov Chain Monte Carlo method, preventing systematic uncertainties from simulated high-z clusters.

We first investigate and discuss whether the presence of massive clusters such as SPT-CL J2106-5844 (z=1.13) and ACT-CL J0102-4915 (z=0.87) is compatible with ΛCDM. The two clusters are the most massive systems in their redshift regimes and were believed to cause some tensions with ΛCDM. However, our WL analysis shows that the two clusters are compatible with ΛCDM, although the two systems are indeed massive.

We then present a WL mass versus X-ray temperature scaling relation for ~40 high-z clusters. Our WL sample size is the largest at $z > 0.8$ to date and includes the highest redshift cluster (JKCS 041 at z=1.8). Our mass scaling relation for high-z clusters follows self-similarity and the evolution effect is not statistically significant. This will serve as a calibrator to determine the accurate masses of more than 1000 high-z clusters discovered in various surveys and their cluster mass function. We also compare the observed mass-concentration (M-c) relation with the theoretical prediction at high-z. The best-fit M-c relation from observation shows a steeper slope than the prediction of N-body simulations. We discuss possible explanations for this discrepancy. Lastly, we confirm that our sample clusters can be found in ΛCDM cosmology.

KEYWORDS weak gravitational lensing, high-z galaxy clusters, dark matter, observational cosmology, mass scaling relation

Division J

#2917

Critical phenomena of quintessential charged rotating AdS black holes surrounded by a cloud of strings

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The main purpose of this work is to investigate the effects of dark energy and a cloud of strings on critical behavior and phase transition of quintessential Kerr-Newman-AdS black hole with a cloud of strings. We give the thermodynamic quantities, such as the Gibbs free energy, heat capacity and the Hawking temperature of the black hole. We examined its equal-area laws, and the critical points are numerically solved for different values of quintessence and a cloud of strings parameters.

KEYWORDS AdS black hole, Quintessence, Cloud of strings., Critical phenomena

Division J

#2536

Enhancing JWST Detection of Low Mass Dark Matter Halos in Quadruply-Lensed Quasars With HST Imaging of Extended Arcs

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In our Cycle 1 program, JWST will provide extremely sensitive measurements of the relative fluxes of lensed quasar images, which in turn will enable the detection of low mass (10^7 M_{sun} and below) dark matter halos. For this to be done successfully, it is necessary to estimate the large-scale mass distribution (macro-model) of the lensing galaxy, which provides a baseline against which the observed image fluxes are compared. I will present new results demonstrating that HST imaging of lensed arcs provides significant additional constraining power on the large-scale mass distribution of the lensing galaxy and therefore enhances our dark matter measurement sensitivity relative to JWST alone.

KEYWORDS Dark matter, Halo mass, Strong Gravitational Lensing, Lensed arcs, JWST, HST

Division J

#2285

Galaxy Clusters at HSC-SSP Wide Survey: A target catalog for PFS up to high redshifts

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Galaxy clusters are the densest regions in the large scale structure of the universe and their study, in several redshifts, allows testing the LambdaCDM model and helps in understanding how baryonic structures formed and evolved. Wide-area optical photometric surveys are a privileged arena for detecting galaxy cluster candidates using only the position and photometry of galaxies. I will present the results of a new cluster finder, optimized for application in the HSC-SSP wide survey. The strategy consists of extensive use of realistic HSC-SSP mock data (PCcones, Araya-Araya et al 2021) to validate selection criteria and tuning probabilistic model parameters in order to calculate the probability of a given galaxy being a brightest cluster galaxy (BCG) and, after, to determine which galaxies are the probable cluster members. Accurate photometric redshifts were obtained through deep learning techniques, reaching dispersions of ~0.025 at $z < 1$ and ~0.05 at $1 < z <\sim 1.5$. Integrated density profile measurements were used to estimate the likelihood of a galaxy being a BCG. The membership probability took into account projection effects and mock cluster member properties. The cluster candidates obtained by this cluster finder can be used as an ancillary database to select targets for the Prime Focus Spectrograph (PFS) Subaru Strategic Program, which will start its operations in 2023.

KEYWORDS Galaxy clusters, BCG, HSC-SSP, PFS, photo-z

Division J

#2257

H0 = (73.37 ± 0.54)km/s/Mpc from a nonlocal dark energy satisfying the BAO and the astronomical age of the Universe

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Recent measurements of the Hubble parameter H0 from the Local Distance Ladder increasingly challenge ΛCDM in Planck analysis of the CMB. Here, we identify this H0-tension with a nonlocal dark energy associated with unstable de Sitter in the distant future. Subject to the Planck measurement of the BAO and the age of globular clusters of the Milky Way, we estimate H0 = (73.37 ± 0.54) km s-1 Mpc-1 (van Putten PLB 823 136737), anticipating H0 = (73.30 ± 1.04) km s-1 Mpc-1 of Riess et al. 2021 (arXiv:2112.04510v2). A testable prediction is a deceleration parameter q0 equal to twice the value expected in ΛCDM.

KEYWORDS H0-tension, Dark energy, Planck, ΛCDM

Division J

#2202

The relation between morphology and star formation history in local cluster galaxies

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One of the main questions faced by modern extragalactic astrophysics is about the origin of galactic properties. While stellar evolution drives the evolutionary paths and timescales of isolated galaxies, galaxies in clusters are subject to a whole range of processes and interactions that dramatically change this picture. To shed light on these issues, we analyze the most homogeneous and complete local cluster galaxy surveys to date: WINGS and its extension OmegaWINGS. We also use stellar population synthesis techniques to obtain properties related to the stars in the galaxies, e.g., stellar mass, stellar ages, star formation rates, and star formation histories.

Our results show that, although the cluster environment eventually shuts off the star formation, several mechanisms at play might instead temporarily enhance it: ram pressure and close encounters with other galaxies can initiate star formation. Likewise, it is of fundamental importance to take morphology into account: while cluster spirals do follow the main sequence of star-forming galaxies, early types display some level of star formation as well, likely triggered by hydrodynamic interactions with other cluster members. Hence, the local environment dominates the stellar population properties, while the global influence of the cluster is likely a secondary agent, resulting from the sum of local ones. In short, the effects of the environment are modulated by galaxy morphology and local density.

KEYWORDS Galaxies, Star formation rate, Star formation history, Environment, Cluster galaxies

Division J

#1987

Testing Web Feeding Model for Star Formation in Galaxy Clusters in the COSMOS Field

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It is yet to be understood what controls the star formation activity in high-redshift galaxy clusters. One recently proposed mechanism is that the star formation activity in galaxy clusters is fed by cold gas and star-forming galaxies in large-scale structures surrounding them, which we call the “web feeding model”. Using galaxies in the COSMOS2020 catalog, with mass completeness at $\log(M/M_\odot) \geq 8.58$ and reliable photometric redshift dataσ $\delta z/(1+z) \approx 0.01$, we study the star formation activities of galaxy clusters and their surrounding environment to test the web feeding model. We first identify the 76 overdense regions at $0.1 \leq z \leq 1.4$ with number density exceeding the 4σ-level from photometric redshift data as galaxy clusters. Furthermore, we identify galaxy large-scale structures and present the anti-correlation between quiescent galaxy fraction, an indicator of star-forming activity, and the prevalence of galaxy large-scale structures. We propose that variation of quiescent galaxy fraction at~1 can be explained by the web feeding model.

KEYWORDS galaxy cluster, large-scale structure, galaxy evolution

Division J

#1939

Spiral disk with concentrated central mass in a Hyper Luminous Infrared Galaxy at a redshift of 4.4

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The scarcity of spatially resolved observations has hindered us from understanding the physical origin of a "starburst" with a star formation rate exceeding 1000Msun/yr, seen in submillimeter galaxies. ALMA's high sensitivity allows us to obtain the most detailed [CII] gas kinematics for an unlensed, hyper luminous infrared galaxy (HyLIRG) at redshift 4.4, BRI 1335-0417. We confirmed the galaxy possesses a rotating disk by quantifying the symmetry of the [CII] kinematics. Analyzing the [CII] kinematics (with a spatial resolution of ~1.1kpc and ~ 8 resolution elements across the disk major axis), we reveal the presence of a central compact structure like a bulge, and a spiral structure on the disk in a galaxy at the redshift of 4.4 (over 12 billion years ago), long before the peak of cosmic star formation. HyLIRGs are thought to be formed mainly through major mergers, but surprisingly the internal structures are rather similar to those of a spiral disk galaxy, with star-forming bulge and disk. Moreover, the dynamical time of a rotating disk (approximate time required to settle the disk after a significant major merger) is estimated to be longer than the gas depletion time scale. This indicates that some additional mechanism other than a major merger is likely to be responsible for sustaining the observed high star formation rate (e.g., rapid accretion from large-scale structure and violent disk instability). These may give us a clue to the detailed formation scenario of HyLIRGs and massive galaxies in cosmic history.

KEYWORDS galactic structure, galaxy formation, galaxy evolution, galactic dynamics, spiral arms, bar, galactic bulge

Division J

#1826

Compact source identification at 90 Ghz with MUSTANG-2

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SZ surveys such as those from ACT and SPT have detected thousands of galaxy clusters, but these surveys are limited in their ability to remove flux from compact sources. Though the impact of sources can be estimated from lower and higher frequencies, any such estimate is prone to large errors as the relevant spectral index is generally unknown. Using a heterogeneous sampling of 30 clusters observed at 90 GHz with MUSTANG-2 (9″ resolution), we analyze the impact these sources will have on survey mass estimates, specifically as estimated for ACT clusters. We also look to ongoing and future MUSTANG-2 work to better constrain the point source population in galaxy clusters at 90 GHz and its impact on cluster detection (and inferred mass estimates).

KEYWORDS galaxies: clusters: general

Division J

#1690

Morphology of Galaxies in the core of Coma Cluster

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We make an in-depth study of the morphology of galaxies in the core of Coma Cluster using the HST/ACS Coma Cluster Treasury Survey. data and the GALFIT lumninosity profile decomposition software. We present bulge-disc decomposition of the sample using GALFIT and obtain parameters for our sample. Using visual inspection of residuals, we do a a morphological classification of the galaxies. We use spectroscopic redshifts to identify the membes and categorize galaxies as dwarfs and non-dwarfs. We find 132 members from our sample of 219 galaxies. In our sample of 132 members, we find 51 non-dwarfs and 81 dwarfs and amongst our 32 non-members, we find 4 dwarfs and 28 non dwarfs. We do not have redshifts for the remaining 55 galaxies. We do a statistical analysis of the morphology of members and non-members. We also study the bulge properties of galaxies using Sersic fits and Kormanday relation. In this talk, we present the structural properties and morphology of the sample of galaxies brighter than 19.5 mag in the F814W band.

We studied the relation of morphological types with Bulge to Total Light Ratio (B/T), color magnitude relation (CMR), Sersic index (n), Kormendy relation and cross-correlations between these parameters for the bulges and galaxies.

KEYWORDS Coma Cluster, Galaxy morphology, GALFIT, Sersic index, Kormendy relation

Division J

#1367

Wide-field Weak-lensing Analysis of the Coma Cluster with Hyper-Suprime Cam Data

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The Coma Cluster is one of the most extensively studied rich galaxy clusters thanks to its proximity (z=0.0231; D~100 Mpc). In-depth investigations of the cluster properties have provided tremendous contributions to our understanding of similarly massive clusters in the distant universe. However, the mass of the Coma Cluster is still highly uncertain. In this study, we perform a wide-field (~3.5 deg x 3.5 deg) weak-lensing analysis of the Coma Cluster using Hyper Suprime-Cam observations. For the first time, we present the weak-lensing mass estimate from the full coverage of its virial radius without any extrapolation. After careful shear calibration, we find that the total mass of the Coma Cluster is significantly larger than previous weak-lensing estimates and spatially resolve the three central mass substructures. We discuss the peculiar central mass peak with no apparent association with bright galaxies despite its high (~8 sigma) detection significance while the other two mass clumps coincide with the two brightest galaxies NGC 4874 and NGC 4889.

KEYWORDS Galaxy cluster, Coma, Weak lensing

Division J

#1246

Bias in weak-lensing mass estimation for merging galaxy clusters

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Merging clusters are dynamically young systems, which cannot be assumed to observe the hydrostatic equilibrium. Weak lensing (WL) is believed to provide an accurate mass estimate as it directly probes the projected potential. However, a recent study has suggested that WL can significantly overestimate the mass of the merging clusters if the evolution of halo concentration is neglected. In this study, we will present our study on the WL mass bias using idealized cluster merger simulations, which investigates its time evolution. With the mock WL data containing realistic observational noise, we found that the weak-lensing analysis overestimates the cluster mass up to ~20% after the first passage and then underestimates it as the system approaches the apocenter. Finally, we apply our results to the three real merger cases: Abell 2034, MACS J1752.0+4440, and ZwCl 1856.8+6616, and discuss the implication of our results for WL observations.

KEYWORDS Galaxy clusters, Hydrodynamical simulation, Weak-lensing analysis

Division J

#1209

MARS Probe of Hubble Frontier Fields Clusters

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We present new strong-lensing (SL) mass models of the six Hubble Frontier Fields (HFF) clusters (Abell 2744, MACSJ0416.1-2403, MACSJ0717.5+3745, MACSJ1149.5+2223, Abell S1063, and Abell 370) with the MAximum-entropy ReconStruction (MARS) algorithm. MARS is a new free-form inversion method, which suppresses spurious small-scale fluctuations while achieving excellent convergence in source plane positions of multiple images. For each HFF cluster, we obtain a mass model after compiling and classifying its multiple images reported in the literature. We are able to obtain quasi-unique smooth solutions regardless of initial conditions for all HFF clusters. This capability has not been demonstrated by other free-form algorithms. We compare our results with previous studies and highlight some interesting scientific cases.

KEYWORDS Galaxy clusters, Strong gravitational lensing, Dark matter distribution

Division J

#991

No instantaneous AGN feedback: Star formation rates determined by SED analysis with JCMT/SCUBA-2 data

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Observationally it is still uncertain how active galactic nucleus (AGN) feedback regulates star formation in massive galaxies despite its importance on galaxy evolution. One of the limitations is that various star formation rate (SFR) indicators are contaminated by AGN radiation. To test AGN feedback scenarios with reliable SFRs, we adopted Far-Infrared (FIR) emission by dust in the interstellar medium (ISM) as a primary SFR indicator since FIR contribution of AGN is negligible. We performed multiwavelength spectral energy distribution (SED) analysis with the assistance of new sub-mm data observed by SCUBA-2 camera at James Clerk Maxwell Telescope (JCMT). By dust luminosity obtained from SED analysis, we determined SFRs of 52 local AGN host galaxies at $z<0.2$, which were sampled by a broad range of [OIII] outflow kinematics. We found that SFR based on Dn4000 break shows a significant offset compared to dust luminosity based SFR, while artificial neural network (ANN) based SFR (Ellison et al. 2016) are relatively comparable. We also found that SED analysis without AGN hot dusty torus component overestimates dust luminosity, especially by a factor of two when both FIR and sub-mm data are unavailable. Finally, specific SFR (sSFR) shows a positive correlation with AGN activity (outflow strength and Eddington ratio), suggesting that there is a lack of instantaneous quenching of star formation due to AGN feedback. This may indicate that AGN outflow requires a certain time scale to quench star formation in its host galaxy, which is called a delayed AGN feedback scenario.

KEYWORDS star formation, active galactic nucleus feedback, ISM, outflow

Division J

#926

Properties of Fast and Slow Bars Classified by Epicyclic Frequency Curves from Photometry of Barred Galaxies

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We test the idea that bar pattern speeds decrease with time owing to angular momentum exchange with a dark matter halo. If this process actually occurs, then the radii of the corotation resonance and other resonances should generally increase with time. We, therefore, derive the angular velocity Ω and epicyclic frequency κ as functions of galactocentric radius for 85 barred galaxies using photometric data. Mass maps are constructed by assuming a dynamical mass-to-light ratio and then solving the Poisson equation for the gravitational potential. The locations of Lindblad resonances and the corotation resonance radius are then derived using the standard precession frequency curves in conjunction with bar pattern speeds recently estimated from the Tremaine-Weinberg method as applied to integral Field Spectroscopy (IFS) data. Correlations between physical properties of bars and their host galaxies indicate that bar length and the corotation radius depend on the disk circular velocity while bar strength and pattern speed do not. As the bar pattern speed decreases, bar strength, length, and corotation radius increase, but when bars are subclassified into fast, medium, and slow domains, no significant change in bar length is found. Only a hint of an increase of bar strength from fast to slow bars is found. These results suggest that bar length in a galaxy undergoes little evolution, and is determined instead mainly by the size of their host galaxies.

KEYWORDS Barred spiral galaxies, Galaxy evolution, Galaxy dynamics, Galaxy photometry

Division J

#800

Medium-band Observation of Neutrino Emitting Blazar, TXS 0506+056

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TXS 0506+056 is a blazar that has been recently identified as the counterpart of the neutrino event IceCube-170922A. Understanding the blazar type of TXS 0506+056 is important to constrain the neutrino emission mechanism, but the blazar nature of TXS 0506+056 is still uncertain. As an attempt to understand the nature of TXS 0506+056, we report the medium-band observation results of TXS 0506+056, covering the wavelength range of 0.575-1.025 μm. The use of the medium-band filters allows us to examine if there were any significant changes in its spectral shapes over the course of one month and give a better constraint on the peak frequency of synchrotron radiation with quasi-simultaneous data sets. The peak frequency is found to be 1014.28 Hz, and our analysis shows that TXS 0506+056 is not an outlier from the blazar sequence. As a way to determine the blazar type, we also analyzed if TXS 0506+056 is bluer-when-brighter (BL Lac type and some flat spectrum radio quasars, FSRQs) or redder-when-brighter (found only in some FSRQs). Even though we detect no significant variability in the spectral shape larger than observational error during our medium-band observation period, the comparison with a data set taken in 2012 shows a possible redder-when-brighter behavior of FSRQs. Our results demonstrate that medium-band observations with small to moderate-sized telescopes can be an effective way to trace the spectral evolution of transients such as TXS 0506+056.

KEYWORDS AGN, Blazar, Neutrino, high-energy

Division J

#796

Photometric Reverberation Mapping with Wide-field IFU Telescope and Medium-bands

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The mass of supermassive black holes (SMBHs) is important in many cosmological study. The reverberation mapping is one of the method to measure the black hole mass. However, the reverberation mapping requires long time baseline of monitoring observation in order to measure the variability of the emission line and continuum flux. It was usually conducted by spectroscopic observation, which consumes high cost and is hard to monitor multiple objects. In this paper, we used medium-band and wide-field telescope to monitor mulitple objects through Intensive Monitoring Survey of Nearby Galaxies (IMSNG). We measured the time lag of 14 emission lines for the 11 quasars and 1 Seyfert 1 galaxy using the JAVELIN and PyCCF. The results are consistent with the previous study in terms of the R-L relation, except for some Hγ time lags. They showed shorter time lag than expected with given luminosity. This is consistent with the photionization expectation. However, the He I time lags did not show any shortened lag, which is expected by photoionization model. We measured the accretion rate of targets in order to find out the lag shortening with high accretion rate target. One Hβ target showed marginally high accretion rate (~ 2) with shortened lag. We measured the black hole mass of the targets and compared the result with the single epoch estimation method. The black hole mass from the reverberation mapping of various lines showed similar result with the single epoch estimation using Hβ line, except for the result using Hγ lines. Therefore, measuring the black hole mass with Hγ needs caution.

KEYWORDS galaxy, AGN, black hole, black hole mass, cosmology

Division J

#759

Formation and Morphology of the First Galaxies in the Cosmic Morning

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We investigate the formation and morphology of the first galaxies in the cosmic morning ($10 \gtrsim z \gtrsim 4$), and their morphological evolution using the Horizon Run 5 cosmological simulation with gravity, hydrodynamics and various sub-grid astrophysics. We measure asymmetry and morphology of stellar mass component of the galaxies with stellar mass M> 2×10^9 M⊙ to classify them into disk, spheroid, and irregular types. We find that the initial morphology of the galaxies in the cosmic morning is dominantly disk type with the Sersic index less than 1.5. The fraction of disk-type galaxies is about 2/3 and that of irregular or spheroid type is about 1/6. Irregular or spheroidal morphology is incidental and transient. The fractions are roughly independent of redshift and also of stellar mass up to 10^10M⊙. Almost all the first galaxies with M > 2×10^9 M⊙ at redshift z > 6 form at initial peaks of the matter density field smoothed with 0.35-cMpc Gaussian filter.

Large-scale structures in the universe emerge and grow like cosmic rhizomes as the underlying matter density uctuations grow and form associations of galaxies in rare overdense regions. The growth of the density field further stretches the realm of the galactic world into relatively lower-density regions along evolving laments. The cosmic web of galaxies forms at lower redshifts when most rhizomes globally percolate. The primordial angular momentum produced by the induced tidal torques on protogalactic regions is correlated with the internal kinematics of galaxies and tightly aligned with the angular momentum of the total galaxy mass. However, the primordial angular momentum only very weakly correlates with the instantaneous morphology and orientation of the stellar component below z = 6. The large-scale tidal field imprinted in the initial conditions seems responsible for the dominance of disk morphology, and for the tendency of galaxies to re-acquire a disk post-distortion.

KEYWORDS galaxies, formation, morphology, high-redshift, cosmological simulation, large scale structures in the universe

Division J

#728

Numerical Simulations of Multiphase Galactic Outflows

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Massive star feedback, including supernovae, radiation, and stellar winds, injects a prodigious amount of energy to the interstellar medium and drives galactic-scale outflows, which play a critical role in galaxy formation and evolution. We have conducted a suite of parsec-resolution numerical simulations using the TIGRESS framework, in which outflows emerge as a consequence of the interaction between supernovae (SNe) and the star-forming, multiphase ISM. The outflowing gas is characterized by two distinct thermal phases, cool (<10^4 K) and hot (>10^6 K), with most mass carried by the cool phase and most energy and newly-injected metals carried by the hot phase. Both components have a broad distribution of outflow velocity, and especially for cool gas, this implies a varying fraction of escaping material depending on the halo potential. Informed by the TIGRESS results, we develop straightforward analytic formulae for the joint probability density functions (PDFs) of mass, momentum, energy, and metal loading as distributions in outflow velocity and sound speed. The model PDFs have only two parameters, SFR surface density and the metallicity of the ISM, and fully capture the behavior of the original TIGRESS simulation PDFs over four decades in SFR surface density. Employing PDFs from resolved simulations will enable galaxy formation subgrid model implementations with wind velocity and temperature (as well as total loading factors) that are based on theoretical predictions rather than empirical tuning. Furthermore, the PDF modeling of outflows provides a new avenue in synthesizing UV absorption line observations.

KEYWORDS Galactic Winds, Supernova Feedback, Multiphase ISM/CGM, Galaxy Formation

Division J

#722

Strong gravitational lensing as a test of the concentration vs virial mass relation

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The concentration-to-virial-mass relation is a well-defined trend that reflects the formation of structure in an expanding Universe. Numerical simulations reveal a marked correlation that depends on the collapse time of dark matter halos and their subsequent assembly history. However, observational constraints are mostly limited to the massive end via X-ray emission of the hot diffuse gas in clusters. An alternative approach, based on strong gravitational lensing over galaxy scales, reveals an intriguingly high concentration at Milky Way-sized halos. This talk focuses on confirming this discrepancy by comparing the observational constraints with state-of-the-art cosmological simulations. We bypass several shortcomings of ensemble type lens reconstruction and conclude that the mismatch between observed and simulated concentration-to-virial-mass relations are robust, and need to be explained either invoking a lensing-related sample selection bias, or a careful investigation of the evolution of concentration with assembly history.

KEYWORDS galaxy formation, galaxy evolution, gravitational lensing, dark matter halos

Division J

#662

TDCOSMO: Lens modelling software comparison and time delay prediction for WGD 2038-4008

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The importance of alternative methods to measure the Hubble constant such as time-delay cosmography is highlighted by the recent Hubble tension. It is paramount to thoroughly investigate and rule out systematic biases in all measurement methods before we can accept new physics as the source of this tension. We perform a check for systematic biases in the lens modelling procedure of time-delay cosmography by comparing independent and blind time-delay predictions of the system WGD 2038-4008 from two teams using two different software programs: GLEE and Lenstronomy. The predicted time delays from both teams incorporate the stellar kinematics of the deflector and the external convergence from line-of-sight structures. The unblinded time-delay predictions from the two teams agree within 1.2-sigma implying that once the time delay is measured the inferred Hubble constant will also be mutually consistent. However, there is a 4-sigma discrepancy between the power-law model slope and external shear, which is a significant discrepancy at the level of lens models before incorporating the stellar kinematics and the external convergence. We identify the difference in the reconstructed point spread function (PSF) to be the source of this discrepancy. If the same reconstructed PSF is used by both teams, then we achieve excellent agreement within 0.6-sigma, indicating that potential systematics stemming from source reconstruction algorithms and investigator choices are well under control. We recommend future studies to supersample the PSF as needed and marginalize over multiple algorithms/realizations for the PSF reconstruction to mitigate the systematic associated with the PSF. A future study will measure the time delays of the system WGD 2038-4008 and infer the Hubble constant based on our mass models.

KEYWORDS gravitational lensing, cosmology

Division J

#565

Mulguisin Clustering Algorithm I. - Comparison of Clustering Algorithms for Study of Cosmic Structure Finding

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We propose a new cluster finding algorithm, MGS(MulGuiSin). This was first introduced in the LHC experiment as a jet finder software and it has evolved into 3d clustering program. The algorithm finds the cluster in the galaxy data like other algorithms used in Astronomy such as FoF, MST. But MGS shows results similar to what the human eye finds and it provides also some characteristic topological informations. In this talk, we describe how the algorithm works in detail and compare the MGS performances with those of other known cluster finder algorithms.

KEYWORDS large-scale structure of universe

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Division J

#527

Tracking Halo Orbits and Their Mass Evolution around Large-scale Filaments

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It has been studied that galaxy halos evolve following a typical trajectory on a phase space under the influence of deep gravitational potential of clusters. Similarly, the large-scale filaments could also affect the evolution of halos before falling into the clusters. In this study, using the suite of dark matter only cosmological simulations called -cluster run, we explore the evolution of halos driven by large-scale filaments in phase space. We find that halos around filaments exhibit phase-space trajectories with similarities as galaxies in clusters. We analyze this phase-space trajectory by exploring correlations between halos' initial position, velocity, formation time, and maximum velocity. We also examine the mass evolution of halos as they become filament halos. It turns out that halos tend to grow their mass when they first approach filaments, but the mass growth slows down around the closest approach to filaments. Around denser filaments, halos can undergo mild mass loss while they sink into filaments. Finally we explain the mass segregation around filaments in observations with halo age and dynamical friction.

KEYWORDS large-scale structure, filaments, dark matter halo, evolution, phase-space

Division J

#348

The Halo Occupation Distribution of HI Galaxies

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The next generation galaxy surveys will provide more precise measurements of galaxy clustering than have previously been possible. The 21cm radio signals that are emitted from neutral atomic hydrogen (HI) gas will be detected by large-area radio surveys such as WALLABY, and deliver galaxy positions and velocities that can be used to measure these clustering statistics. But, to harness this information to improve our cosmological understanding, and learn about the physics of dark matter and dark energy, we need to accurately model the manner that galaxies detected in HI trace the underlying matter distribution of the Universe. For this purpose, we develop a new HI-based Halo Occupation Distribution (HOD) model. This HOD model makes predictions for the number of galaxies present in dark matter halos conditional on the HI mass, and is trained on the Dark Sage gas simulation. The parameterised HOD model is fitted and validated against the simulation, in terms of the mass distribution and galaxy two-point correlation function. We find that the HOD parameters can be modelled by simple linear and quadratic functions of the HI mass. We also explore the halo density profile, and find that the galaxies traced by HI gas in the Dark Sage simulation do not follow the NFW profile.

KEYWORDS Halo Occupation Distribution, neutral atomic hydrogen, galaxy two-point correlation function

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#2973

IAU100: An Exciting Year Celebrating Astronomy

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The International Astronomical Union centenary celebrations (IAU100) in 2019 comprised a year-long worldwide public engagement initiative that celebrated the fascinating past century of astronomical discoveries as well as the importance of astronomy for education, development, diplomacy and outreach. Through the coordination of the IAU100 Secretariat and the IAU Office for Astronomy Outreach (OAO), a combined worldwide effort from the IAU National Outreach Coordinators (NOCs) network, IAU bodies, astronomical organisations, amateur astronomers, teachers, science centres and planetariums implemented the IAU100 ambitious goals. IAU100 exceeded initial expectations with over 5000 registered activities in 143 countries with an estimated further reach of 100 million people through communication activities. Among its global initiatives, we can highlight the IAU100 NameExoWorlds comprising 114 national campaigns to provide names to a star and exoplanet systems or the IAU100 Moon Landing 50 Global Project was the largest coordinated action worldwide celebrating the Moon landing 50th anniversary in 128 countries and regions.

In this talk, we will present an overview of the IAU100 initiative. By discussing its implementation, impact, major highlights, legacies, and lessons learnt, we will present best practices to develop similar transnational large-scale public engagement activities.

KEYWORDS IAU100, Astronomy, Celebrations, IAU, Public Engagement, Outreach, Lessons learnt

OAO
#3434

IAU100 NameExoWorlds: naming stars and exoplanets through the public engagement

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In 2019, the International Astronomical Union (IAU) completed 100 years since its foundation. This important milestone (IAU100) was celebrated with a number of events organized on global, national and regional scales that year, all designed to engage the participation of the public as much as possible. One of the global projects was the IAU100 NameExoWorlds, whose aim was to give people from each country the opportunity to name a specially assigned exoplanet and its host star (visible through a small telescope from the capital of that country) through national campaigns. The National Outreach Coordinators (NOCs) were invited to lead the project and to create a National Committee which would be responsible for running the contest on the national scale. The project finished in December 2019 with the announcement of over 100 pairs of names, all of them proposed by the general public from each participating country. Following the naming rules, the chosen names reflect largely the cultural diversity among the countries, ranging from historical figures, natural wonders, names associated with the night sky in different languages, art expressions and indigenous cultures. This talk intends to show IAU100 NameExoWorlds as a truly successful science outreach project with a strong engagement of the public, implemented essentially by volunteers with time investment from the NOCs and Steering Committee members. We hope that the results help people from all over the world to be connected with the sky through stars and planets named after their own cultures.

KEYWORDS

OAO

#2328

Outreach activities in Egypt

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I would like to share with you the role we play in our societies to communicate and spread awareness of astronomy, as we have revived many of the inspiring and important initiatives of the IAU from the very first celebration of the International Year of Astronomy IYA in 2009 to the celebration of the International Year of Light IYL in 2015, 100 years under one sky 2019. As well as the celebration of the OAO the 100 hours of astronomy, Pro-Am initiative, the annually celebration of the women and girls in astronomy to highlights their role in astronomy ...etc. In this concern, I want to clarify the challenges we faced to communicate with the largest number and how to build bridges and find solutions, since we have always been keen on making the language as clear and direct as possible, always thinking about finding alternative resources and new concepts. Also we are always focusing on finding new ways to attract the interest of more people , in addition to using the human factor if possible, and giving participants a role to gain good experiences, as well as training using multiple senses (visual, tactile, digital, linguistic, etc.). Besides using the different models to encourage the new ideas and the innovations. Recently, and in order to consolidate the goals of the International Astronomical Union of inclusion, diversity and equality, we are planning to organize many events that target sharing of some marginalized groups with the aim of integrating them in the society.

KEYWORDS OAO, Outreach activity, Egypt

OAO

#2698

Astronomy Outreach in Nepal: Creating a Legacy of Science Outreach

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Astronomy has always been fascinating to people particularly children and youths but yet it is one of the confused term or domain with astrology which has deeply rooted impression in our society. This paper will share of our biggest challenge to help people understand the differences of astronomy and astrology and domain they represent. As we found astrology is a part of our culture, we have initiated a dialogue with astrologers in the country to join us to work together in cultural domain in order to document the diversity of understanding of nature by the people in Nepal. It will also share some of the successful IAU Outreach activities that Nepal had decided to run which have helped us to initiative national level dialogue with the government and start collaboration.

It will share the success stories and legacy that has created by International Year of Astronomy in 2009 and IAU100 in 2019. It will also share some of the specific programs that helped us to network with more public using Information and Communication Technology (ICT) such as Name ExoWorld. It will also share some of the challenges we faced and milestones we achieved during our astronomy outreach in Nepal since 2007. It will share how we have used astronomy to create a legacy of particularly science outreach and STEAM outreach in general.

KEYWORDS Astronomy Outreach, Science Outreach, Nepal

OAO

#1969

OAO NOC Spanish activities

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From August 2021 on, the Spanish NOC office is integrated by a three-member team: NOC, vice-NOC and former NOC advisor. Besides keeping ongoing projects and collaborations, we intend to foster and expand new Pro-Am activities as our main goal is to reach out to as many stakeholders as possible. Dark and Quiet Skies initiatives, Inspiring Stars exhibition, Amanar and SKAO NOC funding projects, web and wiki dissemination and/or other IAU-driven projects are some examples among our list of outreach proposals in mind for this triennium. Spain holds a long and sound tradition in amateur astronomy collaborations, a strong implication in outreach from the astrophysical community and proved means for successful international cooperation; our NOC-team will pursue and incentivate all of these issues, among others, the furthest we can. This contribution intends the presentation of a concise summary of Spanish NOC initiatives in general.

KEYWORDS astronomy outreach, Spanish NOC, Pro-Am collaborations

OAO
#2461

Case study: online hands-on astronomy activities for children during COVID-19

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The COVID-19 pandemic has affected many lives and livelihoods, including astronomy outreach. Well into the pandemic, online activities have become a dominant aspect of astronomy outreach initiatives otherwise where we relied on in-person activities for dissemination of astronomy knowledge. But the lack of access and availability of resources in developing countries made it a challenge to be engaged virtually in outreach compared to developed countries. However, the governments in developing countries moved quickly to find ways to continue formal education virtually which opened up an opportunity to introduce astronomy outreach. But we also recognised the rise of 'Zoom fatigue' and other difficulties in staying online for long periods. By acknowledging these challenges, the IAU Sri Lanka National Outreach Coordination team created 'Find Your Way from Stars' as an edutainment activity in collaboration with experts from Astronomy & Society Group, Leiden University, and financial support from the Dutch Embassy in Sri Lanka. The key idea of the project is to include a hands-on aspect but virtually and to promote curiosity and instill a sense of humanity under the same sky. The project took place in February 2021 and allowed students to self-assemble a 3D printed sextant and follow online sessions with experts..Children from Sinhala, Tamil, and English medium schools as well as students with special needs, participated in the project. In the first session, participants assembled a sextant with the aid of a demonstration. All pieces and instruments needed to assemble the sextant were enclosed in a box and posted to the participants in advance. We utilised 3D printing to produce a functional yet affordable sextant and studied the potential of 3D printing in astronomy outreach. Feedback from the parents revealed that the students enjoyed the workshop and engaged with concepts of celestial navigation. We asked for recordings of students instructing their friends on how to use a sextant which revealed that the students have grasped the sextant's functionality and understood the concepts of celestial navigation. With 53.6% of female participation, representing all ethnicities and inclusion of students with special needs, the project became a catalyst in promoting gender equity and cultural diversity across Sri Lanka.

KEYWORDS outreach, COVID19, online, students, astronomy, hands-on, inclusive

OAO

#2651

Astronomy outreach for inclusive environment in Nepal, it's impacts and challenges

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Amidst the ongoing chaos and disturbances, astronomy outreach had been a medication and meditation for astronomy enthusiasts in our group. The increase in the number of genuine astronomy lovers has been a slow process, but the beauty and the impact it beholds have been fascinating a newer group of enthusiasts and young contributors to the society.

Thus, in this regards, my paper will present the increase in the interests of the younger people in this chapter of astronomy outreach in Nepal while describing about the various activities we have been doing with the community of normally-abled, differently abled, underrepresented groups and schools who are giving platforms to the needy group of students in a cascade model. The focus of the paper will be the collaborative approach of Nepal Astronomical society (NASO) with the group of visually impaired individuals, community schools where most of the students come from marginalized and underrepresented communities. It will also showcase the impact created among the all the group of educator and learners along with the challenges we have to face while implementating the activities will also be discussed.

KEYWORDS Inclusive, Astronomy, Differently-abled, Outreach, cascade model, underrepresented, community

Breaking the Barriers:
Adding inclusive elements to astronomy outreach

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The Chilean Astronomical Society (SOCHIAS) has been working for several years to provide fair access to astronomy for all. "The Breaking the Silence" project was born in 2017 with a single goal: to normalize the presence of Chilean Sign Language (LSCh) interpretation in astronomy outreach activities. At that point there were a few outreach initiatives to include the blind and visually impaired (BVI) population into astronomical activities in Chile, but there were none to include those deaf and hard of hearing. The current version of the project, now called "Breaking the Barriers" (BTB), reaches further and seeks to support initiatives to make astronomical outreach activities more broadly inclusive. To achieve this, the project not only provides financial support, but this support can range from advice on how to proceed when catering to groups usually excluded, or provide useful contacts to make the activity more inclusive, or even how to advertise the activity, etc. We strongly encourage those interested in the topic to contact the authors for further details and/or to attend this talk where we will tell the story of the BTB project and discuss the current state of inclusive astronomical outreach initiatives in Chile.

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KEYWORDS Inclusive, Sign language, Outreach, Chile

OAO

#1219

Inclusion and intercultural aspects of Astro-Tourism activities: Astro Camping Project in Djerba: The First step to develop Astronomy in Tunisia

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Tunisia is a country located in the North of Africa, on the coast of the Mediterranean Sea, and also on the edge of the Sahara desert, where tourism represents one of the most important sources of income. It sports a glorious history and exceptional natural beauties since it is reached in archaeological remnants, ranging from Roman mosaics to Arabic art displayed in several Museums and in breathtaking locations. The mild climate of its coasts facing the Mediterranean Sea and the sharp contrast of the fascinating desert of its internal southern regions, together with a relatively low cost of living, make

Tunisia is a preferred touristic destination. Moreover, the southern regions present very favorable conditions for astronomical observations because of the long periods of clear skies and the light pollution is fortunately still very low. Furthermore, many sites are going to be proposed as a possible locations for future astronomical observatories.

Unfortunately, up to date, Astronomy and also any related field, are still absent in Tunisian Universities, in addition, they are no academic astronomical Observatories or dedicated professional instruments for this field of science. However, there are several telescopes used in the context of cultural and associative activities and for general public events, and here comes the role of these activities in presenting the importance of astronomy in developing the quality of education and society. In this work, we are proposing the Astro-Camping project in Djerba, as an initiative to share the astronomical culture and help to develop the study of astronomy in Tunisia.

KEYWORDS Tunisia, Astro-Tourism, Astronomy, Djerba, NOC, Outreach, Inclusion

OAO

#2455

Public Astronomy in Morocco: opportunities & challenges

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Morocco has seen a growing share of public awareness thanks to the efforts of amateur astronomers, educators and communicators, but also thanks to the launch of IAU-OAO Global Outreach Projects, where NOC Morocco has been strongly involved.

Activities that enable personal interaction, such as school visits, stargazing events and festivals, have been considered the most effective in our national outreach experience. However, the development of web conferencing platforms and the creation of social media outreach content have expanded the opportunity to reach the public in new ways through video series, hybrid workshops and online lectures.

In this presentation, I will provide an update on our best practices and lessons learned in outreach, and describe our future projects to inform the public about astronomy, not only from a national perspective, but also from the IAU's public engagement perspective.

KEYWORDS Outreach, Public engagement, National Outreach Coordinator (NOC), Office of Astronomy for Outreach (OAO), Morocco, amateur astronomy, communication

OAO

#2225

Low-cost and Large-scale : a key to reaching most people

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The night skies of rural India (& the world) are pristine and dark, where the numerous stars dazzle & baffle. Unfortunately most of the large population living under them has not much awareness of our current understanding of the Universe. The skies promise amazing deep sky observations even with small telescopes, but the people have never even seen a telescope. This is a challenge for astronomy outreach to most of the world's population that lives far from the mainstream city life. In this context, low-cost telescopes, accessories and other ideas are being used by various outreach groups in India. Many of them use a LIY (learn-it-yourself) approach with an emphasis on hands-on rather than presentations.

This talk will highlight some of these efforts. It will also showcase some well-designed, low-cost alternatives already being used by the IAU NOC India and associates under the "make your own telescope" initiative. These are open source designs and can be customised according to the locally available material. This has led to a network of hobbyists across the country, who made telescope for their own amateur astronomy and who are also willing to voluntarily contribute to outreach. Such constructive efforts are replicable with low costs and have immense inspirational value and a "wow" factor. They could easily be taken up by various IAU NOCs in similar situations, for effectively reaching astronomy through telescopes to many more people.

KEYWORDS Low-cost, Large-scale, Telescope, DIY, India, Outreach, Developing countries

OAO

#1449

A story about astronomy outreach in Vietnam: From an amateur club to a growing #scicomm ecosystem

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Science communication ecosystems are shredding a long-overdue light on astronomy in Vietnam. This year marks the 15th anniversary of Ho Chi Minh City Amateur Astronomy Club (HAAC), the flagship amateur astronomy society of Vietnam. In 2007, HAAC and Ho Chi Minh City Physical Society co-founded Ho Chi Minh City Astronomical Association (HAA). Through the inevitable ups and downs, this first-of-its-kind public-private partnership has been running for five years and it will not stop there. With the mission to truly become the national amateur astronomy society under the brand name VietAstro, the organisation has been doing its best to disseminate scientific knowledge, to engage with the public, to lobby for policy change, and to keep Vietnam in line with the global astronomy community.

Thanks to the valuable support from the IAU Office for Astronomy Outreach (OAO), HAA personnel was appointed the new IAU National Outreach Coordinators (NOC) for Vietnam two years ago. This event opened a whole new chapter for astronomy, especially astronomy outreach, in the country. Since then, the national network of amateur astronomy societies refortified and the calendar of local outreach activities became much busier. Internationally, as IAU NOCs for Vietnam, HAA has continued the existing joint projects and created new ones with its foreign partners. In addition, HAA nominated their external colleagues for vacant IAU National Astronomy Education Coordinator (NAEC) positions. This shows a relay of positive effects for the cause of astronomy communication and education in this Southeast Asian country.

HAA is not all alone. There are other successful initiatives by its core members. Among these, one good example is Saigon Astrokids (SAK), a local social enterprise specialising in outreach activities for children and students up to the age of 15. Furthermore, new partnerships with local schools as well as observatories and science centres have been created to widen the horizons of all concerned parties. It shows the shape of a growing ecosystem for science communication. All of these efforts aim for the clearer visibility and credibility of astronomy in Vietnam. This presentation tells the story of Vietnamese construction of an ecosystem for astronomy communication while highlighting the importance of science outreach to this country.

KEYWORDS IAUoutreach, NOCVietnam, scicomm, VietAstro

OAO

#2771

Space Education and Outreach in Pakistan - Exploration by Yumna

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In Pakistan's Astronomy and Space Sciences field, a lack of awareness was observed in educational institutions and among the public, from outdated curricula in schools that made science uninteresting for students to the militarization of space agency that led to no jobs in the country's space sector. Furthermore, there were no public observatories, planetariums or science museums for students or the public to visit, nor role models or space-career counselling centres where students could progress their professional space careers.

In 2016, a space education and awareness campaign was initiated by Yumna Majeed, then 18y/o medical student and aspiring astronaut. Two years later, Exploration by Yumna was created as a volunteer-run organisation with Ms Yumna as a student ambassador and national coordinator for US and Europe-based space organisations. The mission was to raise awareness about Astronomy among Pakistan's public and promote Astronomy and Space Sciences as a subject and career among students. The target audience was narrowed down to primary and secondary schools.

Since Astronomy is an observational science, using art mediums to engage students in themed activities proved to be a good technique. Teaching methods included presentation based STEM lectures, day and night sky observation sessions via telescope, hands-on activities, space-art and storytelling sessions. To build a sustainable model for the organisation and keep the outreach inclusive and diverse, private schools were charged to cover the material cost, subsequent funding enabling the same sessions to be conducted free of cost at low-income schools, orphanages, and trust schools.

Currently, there's high demand for Space Science workshops, and Ms Yumna reached over 60 schools and more than 7000 children. Schools started to celebrate World Space Week, universities initiated Space Clubs and authorities and the National Space Agency started to address space as part of the course curriculum.

KEYWORDS Space Education and Awareness, Astronomy Outreach, Science Communication, Women in Space, Hands-on learning, Collaborations, Educational Resources

OAO

#1608

Building a network of amateur astronomers in Madagascar

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Over the past few years, a number of astronomy projects and initiatives have been launched to promote Astronomy in all its aspects in Madagascar. This led to an increased interest in astronomy from the Malagasy youth and the general public. However, there are only two astronomy associations that actively run regular outreach initiatives for 22 million people in the country. Such a deficit presents major challenges if one wants to make astronomy accessible to all.

In close collaboration with NOC Senegal and the support from various key stakeholders such as the IAU Office for Astronomy Outreach, NOC Madagascar has recently launched ORION Astro Lab. This is an ambitious project aimed at orienting and transferring skills and best practices to aspiring Astro club leaders. Such an initiative is expected to help lay the foundation in building a strong network of amateur astronomers from scratch. This talk will cover the milestones achieved and also report any challenges and lessons learned along way.

KEYWORDS training, Astro Club, community building

OAO

#3428

The Public Value of Astronomy

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The role of fundamental sciences in society is constantly under scrutiny by policy-makers, academia and society. Astronomy as a flagship fundamental science also needs to justify its work at several levels. The role of public engagement activities with astronomy have been contributing to an increased appreciation of astronomy by society. But a better understanding of the real public value of astronomy is still needed. In this talk, the author will explore the public value of astronomy, namely how astronomy community has been organising itself to maximise this impact. the talk will also explore future directions.

KEYWORDS

OAO

#2976

Commission C2 and its strategic role within the IAU and beyond

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The IAU Commission C2 Communicating Astronomy with the Public has been driving the outreach efforts of the IAU for many years. From it, several key projects of the Union have taken off such as the Communicating Astronomy with the Public Conference, now at its 10th edition or the CAP Journal, currently at issue 30. The Commission also played a key role in the massive IYA2009 campaign, which was a pivotal moment in the outreach and communication efforts of the Union.

More than 20 years ago, the Commission brought together a nucleus of very passionate and highly professional astronomy communicators, who, over the years have dedicated their expertise, one way or another, to growing the community, attracting more members and advancing the profession of astronomy communication.

Nowadays, the Commission works in close connection with the IAU Office for Astronomy Outreach, supporting their projects and the overall strategic goals of the Union. At the same time, the commission works towards achieving the following objectives: encourage and enable a much larger fraction of the astronomical community to take an active role in explaining what we do (and why) to our fellow citizens; act as an international, impartial coordinating entity that furthers the recognition of outreach and public communication on all levels in astronomy; encourage international collaborations on outreach and public communication; endorse standards, best practices and requirements for public communication.

In this talk, I will give an overview of the Commission C2 plans for the current triennium, the opportunities we have for IAU members interested in science communication and the impact we want to bring in our community in the medium-long term. I will also present the way in which the Commission closely collaborates with the IAU OAO and the benefits of working together towards implementing the vision of the IAU for the next decade in terms of communications, public engagement and access to astronomical information.

KEYWORDS outreach, astronomy communication, communication, public, engagement, commission c2, CAP

e-Posters

OAO

#2798

Astronomy with social sense

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In this talk we would like to show experiences doing outreach in astronomy in non conventional escenarios and contexts, where we look for to generate an horizontal knowledge constructions as a tool to improve our outreach activities in astronomy and space sciences. Those new contexts includes market places, and rural areas.

KEYWORDS market place, rural areas

OAO

#1222

Covid 19: How we coped with isolation for astronomical outreach activities?

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The covid 19 pandemic will remain among the most harmful disasters for social activities of our time. General public astronomy, which by its nature encourages exchange between the various intellectual and social strata, has been largely impacted. However, this situation has allowed the emergence of several substitution activities that are not lacking in ingenuity and creativity. We propose here to take stock of some of these initiatives, some of which will now be long-term.

KEYWORDS Pandemic, Outraech activities, inclusion, virtual, remote observatory

e-Talks

OAO

#2963

Astronomical Opportunities in Botswana

Molly Kgobathe[1]

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This position paper will describe the importance of astronomy, how astronomy as a science, as research & an industrial opportunity could offer the ability to increase some sustainable developments opportunities in Botswana. The paper will narrate on the challenges faced in engaging the Botswana community with astronomy and best practices in communicating astronomy to the public.

Astronomy is generally defined as the science study of celestial bodies. In the last century, the emphasis of indigenous astronomies has been on European, Arabic, American, and Polynesian (Holbrook, 1998). The informal / traditional study of stars has been present across the several tribes in Botswana focusing mostly on the star lore. The development of astronomy & space science in Africa has grown significantly over the past few years (Pović, et al., 2018). Therefore, formal studies of astronomy in Botswana have contributed to the statistics of astronomy growth in Africa. The Formal education of Astronomy is mostly visible at tertiary level. Botswana has been in its infancy level for the past 3to 4 years due to corvid pandemic. Botswana is one of the best locations in Africa to view wildlife and the clear skies as it has relatively low levels of light pollution (O'Meara, 2020).

Currently Batswana has a handful local astronomers which are mostly astronomer enthusiasts. Most of the expert astronomers are expatriates & recent astrophysics graduates. Recently most locals are now seeing the significance of astronomy as a sustainable development initiative. There is a need for a lot of astronomy outreach to be done locally regarding the clear skies with data that needs to be readily available for those interested in astronomical issues in Botswana.

The paper will point out the significance of astronomy and its sustainability methods to benefit locals. This research is useful because it will demonstrate how astronomy challenges can be used to support decision making in the domain of human capacity development & evaluations. Astronomy innovations and existing astronomical stakeholders' focus on the initiatives based on education and /or tourism. Although different conclusions can be reached through the evaluations, many of the approaches used for astronomical outreach activities have been mostly physical, but corvid-19 pandemic has resorted online.

KEYWORDS astronomy, Opportunities, education, industrial, sustainable development, human capacity, strategy

OAO

#2962

Virtual Outreach Programme as an Alternative Platform in Delivering Astronomy Education: A Case Study in Malaysia

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Introduction. The National Planetarium of Malaysia is a non-formal astronomy education centre in Malaysia. Over the last three decades, it has become one of the most widely recognised centres in Malaysia. It has organised many outreach programs based on astronomy activities to cultivate space science enculturation thinking for the general public. The primary objective of the establishment of the National Planetarium is to raise public awareness of the importance of astronomy and space science through various outreach and inreach activities in National Planetarium.

Challenges. About one-fourth of Malaysia's population is rural. Although rural areas have been the focus of physical infrastructure development, they still lag when it comes to accessing quality education, including for the area of astronomy. In addition, despite the support received from the government, National Planetarium is still facing challenges in engaging the community, especially in rural areas. Many programs that National Planetarium has organised are either not accessible or unreachable to this community. The COVID-19 pandemic has worsened, especially in the first year of the pandemic, the year 2020. The numbers of programmed and people engagement dropped significantly. Learning from that scenario, National Planetarium started designing and implementing the various virtual astronomy programme.

Effort. Recognising the vast challenges of continuously educating the general public, especially students during the pandemic era, National Planetarium believes in the need to develop alternative learning platforms to bring astronomy closer to the public. Therefore, National Planetarium has created a virtual learning platform and, at the same time, converted most of our physical programme into online mode. One of the signature programmes is establishing the "e-planetarium" platform. With the platform, most (if not all) of our National Planetarium services transformed into online mode. This includes seat booking, ticket purchasing, online notices etc.

Conclusion. A virtual outreach programme is an alternative platform for delivering astronomy information to the public through an edutainment approach.

KEYWORDS astronomy education, virtual education, online education

OAO

#2802

Observation of Chinese Space Station as a Tool to Promote Public Attendtion to Night Sky and Astronomy

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Constrcution of the Chinese 'Tiangong' Space Station (CSS) will be completed at the end of 2022, which makes CSS one of the brightest artificial objects above night sky. Observation of the visible transits of artificial satellites is a good way in the new era of space stations and starlinks to make public interested in night sky and be familiar with magnitude, azimuth, altitude as well as the bright stars with background constellations. Observation tips for CSS are suggested with astronomical photograph using camera or mobile phone under different situations, and some results from CSS observation activities for general puclic and students are discussed.

KEYWORDS satellite observation, Chinese Space Station, night sky

OAO

#1103

Inspiration of IAU 100: New Approaches of Astronomy Communication (in Hong Kong) during COVID-19

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IAU 100 was an iconic global celebration of the 100th anniversary of the International Astronomical Union. It gathered astronomy professionals and educators around the world to connect with each other, with the common goals of spreading astronomy knowledge, facilitating science communication without barriers, and protecting our night sky. Despite the unexpected occurrence of COVID-19, astronomy outreach and education in Hong Kong, as a case in point, continues to explore new approaches and strategies with the continuous support of the IAU Office for Astronomy Outreach. Through STEM+A@Astronomy social innovation approaches, it was encouraging that the interconnection of astronomy and other disciplines could arouse people's awareness and engagement in promoting popular science in OAO projects, such as 100 Hours of Astronomy celebration, Dark and Quiet Skies projects, and Online Astro@Home events.

KEYWORDS IAU100, science communication, astronomy outreach, astronomy education, Astro@Home, Dark Sky, 100 Hours of Astronomy

OAO

#1298

NOC Activities carried in Greece in collaboration with IAU/OAO, 2022

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I will briefly present at first, the very successful and important legacy of the IAU100 celebrations-activities in Greece. Then I will focus on the challenges we faced in continuing the engagement of the greek community with astronomy. After the Educational NASE/IAU seminars on Astronomy and Astrobiology, for educators, February and March 2021, were almost 200 teachers, all over Greece attended. https://astronomy.arsakeio.gr

We included the

- 26th Summer school of the National Observatory of Athens, in Astrophysics (1-2 September 2021) for high school students all over Greece with almost 100 students all over Greece.

https://www.astro.noa.gr/en/public-outreach/summer-school-of-astrophysics/

Then for 2022, we choosed the key topic 2.4) "Dark and Quiet Skies Protection and the Pale Blue Dot message"; introduced by OAO, as the main and most suitable vechile to introduce our next activities since it is a field of research that spans in many different disciplines. The practice we choosed to be effective advocate for dark-sky protections, is based in science facts and the latest results in the science of light pollution. In that way we are trying to bridge outreach with research, education and development, building a framework of collaboration.

In particular we are organizing a two-days on-line conference, for all over Greece. The first day is dedicated on the science of Light-Pollution presented by IAU-greek members specialists and specialists from other disciplines. The second day will be dedicated on the engagement of school community in activities with Professional-Amateur relations and Citizen Science activities. Additionally we placed this conference on the 16-17 th of May, as it was suggested by OAO. Our practices in communicating astronomy to our community;and the initiatives we have been engaged with as NOC representative, is totally in alignment with the relevant OAO session. The support and inspiration we got by OAO is essential. The results will have been qualified by the time of the GA, and will be presented.

KEYWORDS The legacy of the IAU100 Celebrations, Dark and Quiet Skies Protection, Bridging outreach with research, education and dev

OAO

#1197

AstroTalk project: A new challenge within the COVID-19 pandemic

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In 2020, and within the COVID-19 pandemic and the lockdown in several countries, many persons have been suffering from isolation and the cancellation of most meetings, and in some cases the closing of schools, universities and the prohibition of public events. During this pandemic, the NOC office in Tunisia and in collaboration with several national and international astronomical communities remoted an online project that was based on weekly online lectures for the public and amateur astronomers. This project was initiated in order to keep the science communication and the practices in communicating astronomy to your community in a very difficult time that was facing the global planet. The Astrotalk project displays the ability to communicate science and astronomy not only on a national scale but also international scale since the project was extended afterward to reach many NOCs and astronomers in diverse continents and many countries.

The Astrotalk project is still in progress, and we are aiming to reach and collaborate with all the OAO National Outreach Coordinators, to promote bridges of science communication and future projects in the near future and help connect the diverse astronomical groups over the world. Moreover, we will demonstrate the role of the AstroTalk project in providing one of the OAO objectives in linking the different NOCs and helping construct a multi-cultural and multi-aspect working environment. The project have been initiated in 2020, and it has been selected for the third Award within the Astronomy@Home Awards 2020 context it has been classified as the first Outstanding Online Event.

KEYWORDS Tunisia, Lectures, Astronomy, Pandemic, NOCs, Outreach, online

OAD
Office for Astronomy Development

Invited & Contributed Talks

OAD

#3041

Overview of OAD activities

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The IAU's Office of Astronomy for Development has been part of the astronomy landscape for over a decade. In this talk, we focus on the role that astronomy can play in socioeconomic development, and why the activities of the OAD are just as relevant now as they were a decade ago. Using the sustainable development goals as a guide, we illustrate the impact of various astronomy for development activities, ranging from the annual call for proposals to the potential of flagship projects.

KEYWORDS

OAD

#3042

The changing shape of science diplomacy – the role of the International Science Council

Peter Gluckman[1]

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Track 2 science diplomacy was very valuable in the cold war years where the ISC's ancestor organisation, ICSU, made important contributions. It seem probable that as the world enters a period of geopolitical tension, track 2 diplomacy will again be critical. Covid has shown how multilateral scientific cooperation can succeed even when the formal multilateral system was weak. But the emergence of many new technological innovations creates a new set of challenges for science diplomacy. These will be discussed. Beyond that the formal role of science within the multilateral system is disparate and often weak. The ISC is taking a lead in conversations regarding these deficiencies.

KEYWORDS

OAD

#3043

External review of the OAD

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The most recent external review of the OAD took place in March 2021, entirely virtually because of the Covid pandemic. In this presentation I will summarise the review methodology, its outcome and its key recommendations, explaining why the reviewers found that the performance of the OAD had been outstanding and therefore recommended that the OAD should continue at the SAAO with support from the IAU and the National Research Foundation of South Africa.

KEYWORDS

OAD

#969

10 Years of Astro4dev Projects: Case Studies from Around the World

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Ten years ago, the Office of Astronomy for Development launched its first open call for development proposals. Since then, the OAD has coordinated ten annual calls for proposals, funding more than 200 projects and reaching people in more than 100 countries. These projects, run by teams of scientists from astronomy, physics, and social fields, as well as students and various professionals, have sought to resolve local and global challenges using astronomy and science. Many of the projects are successful examples of science for development in action. And they have influenced the development of the OAD's Flagship programs. Examples include community astro-tourism, astronomy to inspire children at refugee camps, astronomy-based programs to teach critical skills for the job market such as programming and data science.

This presentation will cover some of the ways that projects have tackled developmental issues through astronomy. It will provide overall statistics of impact from OAD projects, describe a few case studies of projects that worked well, those that did not work well, and discuss possible reasons.

KEYWORDS development, SDG, astrotourism, refugee camps, astro4dev

OAD

#423

Linking the outcomes of the IAU OAD Projects to the UN Sustainable Development Goals (SDGs)

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[1]Analysis and communication of OAD projects, IAU Office of Astronomy for Development, Romania

With the opening of the IAU Office of Astronomy for Development (OAD) in 2011, the IAU has taken significant steps on the path of science for sustainable development. From 2013 to 2021, the IAU through the OAD has funded over 180 projects. In our analysis of this portfolio of projects, we looked at the outcomes of these projects and compared them to the UN SDGs and the related SDG targets. We find that the OAD projects have contributed to at least 9 out of a total of 17 SDGs defined by the United Nations (UN). Within each sustainable development goal the IAU OAD projects touch on multiple UN defined targets which speaks once more about the diversity of the IAU OAD projects. We will present here an in-depth analysis of the diversity of IAU OAD projects, showing trends with geographical areas projects originate from and with the needs addressed by the projects.

KEYWORDS Astronomy for Development, Sustainable Development Goals (SDGs)

OAD

#2839

The Impact of IAU OAD Projects on UN Sustainable Development Goals

María Alejandra Díaz Teodori[1]

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In 2015 the United Nations General Assembly set 17 Sustainable Development Goals (SDGs) with the aim of creating a sustainable future for humanity by 2030. Each Goal has several Targets, and Indicators to check if those Targets are met. Since its opening in 2011, the IAU Office of Astronomy for Development (OAD) has funded and coordinated over 180 projects that use astronomy as a tool to address issues related to sustainable development. Previous analyses of a portion of the projects had shown evidence that OAD projects consistently contribute significantly to at least one Target, and that there are contributions to at least 8 SDGs. Now an in-depth study of the full scope of the projects throughout the years is being conducted, and we will present an analysis of their impact on sustainable development, as well as statistical trends in geographical location, year, and funding.

KEYWORDS sustainability, UN, development

OAD

#327

Astronomy Education Outreach Efforts for Development in Africa

Olayinka Fagbemiro[1]

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The Astronomy Without Borders (AWB) Nigeria has been a major player in the effort to take Astronomy to every part of Africa. In order to popularize Astronomy, especially among young kids across the African Continent, the Africa Astronomical Society (AfAS) has intensified effort in her quest to see that Astronomy becomes a household name across Africa.

AWB Nigeria has been involved in a lot of Astronomy Outreach activities to get young kids, irrespective of their socio-economic backgrounds, interested in STEM through Astronomy. These activities include school outreaches, Teachers Training, Internally Displaced Peoples' camps outreaches, public outreaches among others.

Due to the fact that Astronomy is not being taught at the Elementary and High School levels in many African countries, it has become imperative that kids have encounters with Astronomy through extra-curricular approaches. Also, getting STEM teachers at these levels involved in training on how to extract Astronomy related topics from existing subjects being taught in school has become very important.

Astronomy is being used as an important tool to popularize STEM and help the continent develop technological capabilities. With relevant hands-on approaches in teaching Astronomy to kids, Science Technology, Engineering, and Mathematics (STEM) are being demystified and kids now understand that STEM can be fun to learn.

Parts of the efforts also include deliberate and purposeful approaches to close the gender and economic gaps that exist in STEM education on the continent of Africa. Targeting kids from extremely poor backgrounds, kids from the internally displaced peoples camps (IDP) who have been traumatized by the insurgencies in northern Nigeria as well as young girls who are mostly out of school or on the verge of dropping out of school, it is only a matter of time before these efforts translate into a major breakthrough in the developmental growth across the continent.

KEYWORDS Hands-on, IDP, STEM, Development, Capabilities, Outreach, Education

OAD
#2203

Impact of IDP Children Astronomy Outreach Project: A Data driven approach

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The IDP-CAO project aimed to use Astronomy as a tool to counsel, heal and inspire children that have been displaced due to terrorism in Nigeria. The project was executed in 2 different IDP camp in FCT-Abuja, Nigeria in 2019 and 2021. The children have been exposed to astronomy via the Solar powered learning hubs in their camps.

As part of the project, the children were evaluated using psycho-social assessment (Cognitive-Behavioural therapy assessment) and their interest in Astronomy have been evaluated. This paper will evalaute the impacts of the project and measure the changes since the execution of the project using Data that have been recorded.

KEYWORDS Internally Displaced Persons, Astronomy, CBT Assessment, Data driven approach

OAD

#2018

Investigating the effect of using the "Talking Planets" mobile application to increase students' engagement and knowledge of astronomy

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This study examines the effect of the "Talking Planets" android mobile application (funded by the International Astronomical Union's Office of Astronomy for Development) on school students from 4th to 9th grade and their attitude toward the application. Talking Planets is an educational android mobile application (currently in beta version, not available in Google play store yet) to make school children aware of astronomy, more specifically the planets of our solar system. This mobile application presents different planets as funny characters and students will be able to chat with these characters and find out about them by asking different questions. That is, the characters of the planets will behave like chatbots.

In this study, students (n=79) from two schools used our developed mobile application, Talking Planets. The study was conducted on 15 and 17 March 2022. The study investigated whether students learned anything new about astronomy after using our mobile application. Students' knowledge of astronomy was assessed before and after using the mobile application by providing the same question paper. 47.1% of students were able to increase their knowledge assessment performance, 35.44% of students' performance did not change, and the remaining 16.46% of students' performance was decreased. The outcomes suggest that this application has great potential to increase the knowledge of astronomy among school students. The attitude of the school students toward the mobile application was evaluated by an anonymous survey form. The students showed very positive attitude toward using the mobile application, its effectiveness, and user-friendliness.

KEYWORDS Mobile learning, Attitude, Engagement, Mobile application, Children, OAD, Astronomy education

OAD

#2222

Central American — Caribbean Bridge in Astrophysics

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The Central American and Caribbean Bridge in Astrophysics (Cenca Bridge) is a ground-breaking, graduate student-led program to expand astrophysics research opportunities for undergraduate students in the region, with a focus on inclusive astronomy. Cenca Bridge organizes a remote research internship program twice a year, connecting undergraduate students with international astronomers to take part in astronomy research over a period of 3 months, with continued near-peer mentorship to support the students' success. Other activities to support our mission include monthly research seminars, professional development workshops, coding/programming workshops, and providing a platform to discuss social justice issues. This talk will focus on highlighting the growth and success of the program over the last few years and future plans.

KEYWORDS Astrophysics, Central American, Caribbean, undergraduates, equity and inclusion

OAD

#1271

Astronomical heritages and facilities in Tunisia

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Dates back to around 1981, the Youth and Science Association of Tunisia (AJST) - Nabeul Club, represented by Habib Zangar, Faouzi Zaghbib, Slim Mamouri, and Henri Monreal, in collaboration with some students from the Higher National Engineering School of Tunis-ENIT, succeeded to build the first astronomical observatory in Tunisia, which is located in the coast of the Nabeul city. This astronomical observatory was mainly dedicated to outreach activities of the AJST and public events. Although the observatory was in a strategic location for public access and in close vicinity to schools and institutes, the geographic location was not very adequate, since it was close to the sea, and consequently, the building was damaged by the high humidity and the salinity of the water. A few months later, the astronomical observatory of Nabeul was closed, for safety reasons, since the building was in a bad situation and all equipment was taken away for independent use in open space, and the observatory was saved as a historical monument.

Thirty-seven years later, and in August 2018, a group of amateur astronomers from the Youth and Science Association of Tunisia- AJST, Djerba Club, directed by Lassaad Akrout, decided to build an astronomical observatory with personal funding and a local donation from citizens without any support from the governmental institutions and the concerned ministries. The Observatory is located on the roof of a Mosque, in an isolated zone, far away from light pollution under a nearly dark sky, and in an easily accessible location. The main objective of this observatory is also outreach activities in the context of the AJST events and summer schools.

Besides the astronomical observatory of Nabeul and Djerba, Tunisia owns many important organizations that hard work to sensitize the public about the importance of astronomy, astrophysics, and space sciences in the development of education quality and equal society. In this work, we will present the astronomical heritages and the facilities in Tunisia as a country in the stage of developing astronomy and space sciences with its society and join the parade of space and universe exploration.

KEYWORDS Tunisia, observatory, Astronomy, heritages, facilities

OAD

#695

Astrotourism around the middle of the world

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Ecuador, recognized as an attractive travel destination, has more natural sites to visit than the Galapagos Islands, nevertheless, continental and rural regions remain still unexplored. Ecuador is one of the countries where the equatorial line crosses and played a fundamental role in the French Geodesic Missions. On the coast of Ecuador in the province of Manabí, there is an iconic place where astronomy has to converge during the whole story of the country. Before the Incas, cultures such as Valdivia (3000 B.C), Jama Coaque (500 B.C) show an understanding of astronomical phenomena on the archaeological register. In the modern era, the French Geodesic Mission in 1736 arrived at Punta Palmar, in Manabí-Ecuador, and determined the first 0º Latitude point for the geodesic measurements. Currently, studies on astroparticle physics have been proposed since the 0º Latitud offers the highest magnetic rigidity for particles coming from different astronomical sources at different altitudes.

Unfortunately, the region of Manabí is one of the poorest regions of the country with problems on education, gender and economical inequality, natality, and lack of services. Nevertheless, although Manabi is known as one of the best tourist places in Ecuador due to its gastronomy and beautiful beaches, it lacks places to stay making experiential tourism undeveloped.

This project aims to develop: (1) experiential tourism in La Chorrera around the concept of "the Middle of the World" and the formal studies of the physical phenomena of this region, and (2) to create a space for undergraduate students to use technical skills learned in their institutions for the benefit of the community.

This initiative aims to complement the ongoing project of the Coaque Astronomical & Archaeological Museum and contribute to sustainable rural tourism. The developmental goal focuses on the idea of building sustainable work possibilities for the inhabitants of La Chorrera and the nearest coastal equatorial regions, involving academia in the solutions of the social problems of Ecuador

KEYWORDS Astrotourism, Ecuador, French Geodesic Mission, zero latitude

OAD

#1708

Astronomy Education during the pandemic

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During the pandemic, we were involved in two IAU-OAD Projects "Astronomy from Archival Data "and "AstroSprint" both of which involved training undergraduate and postgraduate students on astronomy projects using archival data. Using open source software and virtual observatory tools they were trained to work on ressearch projects. A series of workshops in online mode enabled students to make use of their time to study astronomy science cases in detail. We had almost 1000 registrations from students belonging to almost 25 countries. Online sessions of 1.5 hours are conducted on weekends (Saturday and Sunday) with recorded sessions available on youtube for students depending on their time-zones and work constraints. The ongoing project AstroSprint, is an extension of the earlier project and consists of three meetings: Enterprise, Discovery and the Next Gen. Both these projects will be discussed in detail with the challenges and caveats involved.

KEYWORDS Archival data, Astronomy Projects, Virtual Observatory, Education

OAD

#3044

Astrostays : Creating sustainable livelihoods through Community Led Astro-tourism

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Astrostays is a community-led Astro-tourism initiative that merges Astronomy and community development interventions for creating sustainable socio-economic opportunities for indigenous communities in rural areas. With the community at the center, the model goes beyond traditional astronomy-based offerings – bringing economic benefits of tourism directly into villages - transforming rural homestays into Astronomy Hubs and holistically empowering local communities. Trained on basics of astronomy and know-how of operating telescopes, the local homestay owners (mostly women) conduct night sky gazing sessions for the tourists, creating a new channel of revenue generation, that has eventually led to increase in stimulus to local economy, reducing youth migration and preservation of age-old Himalayan heritage.

KEYWORDS

OAD

#2656

Astronomy for Mental Health

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Mental health is our fundamental human right as much as physical health. In fact, it is even more important, as there is "no health without mental health" - a central principle in global health actions (i.e. WHO Comprehensive Mental Health Action Plan). Globally there are close to one billion people with mental health disorders. Though invisible and overlooked, these issues have a major impact on quality of life, health, education, employment, and social relationships of people. As a crucial factor for development, mental health is part of the UN development agenda. SDG 3 commits to promote mental health and well-being. Still huge treatment gaps remain. The COVID-19 pandemic became a major wake-up call for the need of mental health support.

The astronomical community has worked, for many years, toward creating a better world. Astronomy is deeply rooted in our history and culture as human beings, and can be an excellent tool to promote change and address the UN Sustainable Development Goals. Astronomy perfectly combines the feeling of awe produced by looking at the vast, starry sky with being located in a (nocturnal) natural environment, which contributes to increased positive emotions and reduced negative emotions, and has a huge potential to be a unique and strong tool for mental well-being.

OAD's Astronomy for Mental Health project aims to explore how the inspirational and cultural aspects of astronomy can help improve the mental well-being of vulnerable communities (refugees, displaced people, people in disaster zones, etc.), as well as other groups negatively affected by the pandemic (elders, women, youth, migrants, etc.). The project relies on multidisciplinary collaboration between the astronomy community, psychologists, mental health specialists, educators, humanitarian workers and others. The results of this collaboration and the findings of the project will be presented during the OAD session at the IAU General Assembly 2022.

KEYWORDS mental health, astronomy, well-being, SDG, development, awe, inspiration

OAD

#2770

Data Science Exposure through Astro4dev Hackathons

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The technological advances resulting from the fourth industrial revolution, as well as the need for data-driven solutions for a myriad of problems, have resulted in a demand for individuals with skills in data science. Data science and machine learning are valuable, transferable skills often used in the astronomy field. Exposure to such skills can result in broadened study and career prospects and may therefore positively impact socio-economic development. The Development in Africa with Radio Astronomy (DARA) Big Data project was established in 2017 with the aim of building human capital in data-intensive research in South Africa and the eight SKA African partner countries. The Office of Astronomy for Development, in partnership with DARA Big Data and IDIA, have held Big Data Hackathons in order to increase exposure to data science and machine learning in Africa. With the project coming to an end this year, the focus is now on the collation and distribution of the programme's resources in order to allow for long-term impact of the project through self-organised data science skills development hackathons globally.

KEYWORDS data science, skills development, hackathon, machine learning

OAD

#2397

Development of Modern Astronomy in the Korean Peninsula

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Although Korea has a long tradition in astronomy going back to the pre-historic period, the development of modern astronomy has been significantly delayed because of the turbulent history during the 19th and 20th centuries. In 1945, Korea became divided into two countries, North Korea and South Korea, on both sides of the 38th parallel. Western astronomy was occasionally introduced to Korea in the 18th century mostly through China, but it was not widely taught until after the "Korean war" between the two countries (1950-1953). In South Korea, university-level astronomy education started in the late 1950s, the Korean Astronomical Society was founded in 1967 and the National Astronomical Observatory was established in 1974 together with the installment of the first research-grade telescope. In North Korea, Pyongyang Astronomical Observatory, effectively its National Observatory, was established in 1957. Astronomy and astrophysics in South Korea are now in mature state thanks to the aggressive investments by the government, enthusiastic support by the general public, and hard work by the pioneers. South Korea became a member of the IAU in 1973 and now has a membership of more than 180 astronomers. In the meantime, there was very little contact between North and South Korea even in scientific activities including astronomy. North Korea became a member of the IAU in 1961, twelve years earlier than South Korea, but there have not been many occasions for astronomers on both sides to communicate with each other within the IAU or outside of it. This talk summarizes the early development of modern astronomy in South Korea with brief accounts of efforts for scientific collaboration with North Korea.

KEYWORDS History of Astronomy, Observatories

OAD

#1438

Astronomy in the Crossroads of Inter- and Multi- Disciplinary Sciences

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Interdisciplinary and multidisciplinary sciences over the last few decades have become the major booster of science development. The most important discoveries occur just at the intersection of sciences and in collaboration of several fields. There appeared such intermediate fields as mathematical physics, physical chemistry, biophysics, biochemistry, geophysics, etc. In Astronomy, Astrophysics has long been the main field, and in present Archaeoastronomy, Astrochemistry, Astrobiology, Astroinformatics (which is tightly related to Virtual Observatories) are developing. On the other hand, in recent years many science areas surfeit of research on Earth, more and more use data coming from the Space and are being developed just due to them. It is possible that soon, various science areas create Space departments or simply develop their research in close collaboration with astronomers. Interesting discoveries have been made in studies of astronomical topics in various areas of culture; such topics are widely used in folklore, other genres of literature, painting, and architecture. Astronomy has also a leading role in Scientific Tourism, Scientific Journalism and in general, dissemination of popular science or public outreach. We plan to use the leadership of astronomy in development of interdisciplinary and multidisciplinary sciences and expand the role of our regional office by involving more Astrochemistry, Astrobiology, Planetary Sciences (Astrogeology), Astroinformatics, Archaeoastronomy and Cultural Astronomy.

KEYWORDS Interdisciplinary and multidisciplinary sciences, Astrochemistry, Astrobiology, Astroinformatics, Virtual Observatories, Archaeoastronomy, Planetary Sciences

OAD

#2628

Role of Science in Development – the case of Astronomy

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Astronomy assumes a critical role in shaping our understanding of the cosmos and our place in it, given that our identity as the human species is intricately connected to the stars. Against this backdrop, the Office of Astronomy for Development (OAD) of the International Astronomical Union (IAU) was established to work on using astronomy to help achieve development-related outcomes. Guided by the Sustainable Development Goals (SDGs), this is achieved via project funding and other activities. The proposed talk adopts a theoretical approach in establishing the role of astronomy in development, for example by linking the “Science for a common humanity” flagship of the OAD to the work of Elianor Ostrom (an economist) that is grounded in communities co-existing and working cohesively together to achieve common goals. The talk focuses on the development context, setting the stage for equipping scientists with the tools they need in executing their development work; for example, by highlighting that, in settings where the development base is low, small investments made by scientists (or science organizations) working in the community (in Observatories for example) can have significant domino effects. Reference here is made to work done in Sutherland (South Africa) by the OAD to gather perspectives on the role the South African Astronomical Observatory (SAAO) has played in the development of the local town. The COVID-19 pandemic presented formidable challenges to society, yet the response from the science community helped to defend humanity. The talk also chronicles important strides made by the scientific community in South Africa and elsewhere to design and manufacture equipment which was in short supply at the beginning of the pandemic such as ventilators. Lastly, the talk highlights the leadership role played by scientists as community leaders in helping disseminate the right information and counter disinformation.

KEYWORDS astronomy, development, investments, scientists, leadership

OAD

#1570

Global structure in astronomy-for-development: a case of East African Region

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The global coordinating office of Astronomy for Development (OAD) was established in 2011 in response to the IAU's visionary decadal strategic plan titled "Astronomy for the Developing World," which aimed to use astronomy to stimulate development at all levels.

The OAD has already created 11 Regional Offices and Language Centers across the world, each of which shares the OAD vision but focuses its efforts on a specific geographic, cultural, or language location. The East Africa Regional Office of Astronomy for Development (EA-ROAD) is one of the OAD's regional nodes in Eastern Africa, which was established in 2014 and is hosted by Ethiopia.

The purpose of this talk is to review and highlight the key activities of the regional office over the last five years, with a focus on implementing IAU and OAD strategic plans, coordinating and guiding regional flagship projects and workshops, working on the three task forces (Children& Schools, University& Research, and public outreach) in line with the goal of astronomy for development and developing regional and international cooperation.

KEYWORDS Astronomy for development

OAD

#1327

Space Activities, Laws, and Regulations in the Arab World

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Although all Arab countries have made use of satellites and space data for applied purposes, such as remote sensing, weather forecasting, communications, navigation and so forth, very few of these countries have actually been able to manufacture their own satellites, and fewer still have developed their own national space agencies and space laws. However, space activities have started flourishing in most Arab countries during the last 5 to 10 years, especially with the spread of the low-cost nanosatellite technologies, among other reasons. Still, the most important Arab space activities and their related legal issues that are worth mentioning here are probably those related to the Kingdom of Saudi Arabia (KSA), which was the hub for the Arab Satellite Communications Organization; to the Arab Republic of Egypt with its relatively early interest in satellite technology; to the United Arab Emirates (UAE), which is now playing a leading role at the Arab level in space exploration and satellite applications; and to the Arab Group for Space Cooperation.

KEYWORDS Space Activities, Sustainable Development, Arab Satellite Communication, Arabsat, Arab Group for Space Cooperation

OAD

#432

Activities of the IAU E-ROAD and its flagship project Pale Blue Dot

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The IAU Office of Astronomy for Development and its network of regional offices across the world help further the use of astronomy as a tool for global development in order to realise the field's scientific, technological and cultural benefits to society. It aims to positively impact development and specifically on the UN Sustainable Development Goals (SDGs). The European Astronomical Society together with Leiden Observatory is running the European Regional Office of Astronomy for Development (E-ROAD, www.astro4dev.eu/about-us). The office aims to connect and involve the European astronomy community to learn from each other and make the E-ROAD an initiative where all astronomers can contribute. The vision for the office is that by 2030, the European astronomical community contributes significantly to sustainable development and the SDGs at local, regional and global levels. Last year, a new 6-year strategic plan was developed. Currently, the E-ROAD has national representation in 21 countries and it is still actively mobilising human resources across the continent to implement its strategic plan. In this talk, the various initiatives of the office will be highlighted. The E-ROAD team and representatives came together in the effort of writing several funding proposals to stimulate astronomy for development in Europe. The office is building human capacity by training astronomers and students in transferable skills through Erasmus+ twinning collaborations. Besides, the H2020 SKIES project focusing on training young astronomers in social innovation and entrepreneurship skills has almost been completed and its outcomes will be shared. Finally, in the OAD flagship project Pale Blue Dot that is carried out by the E-ROAD, astronomy education is used as a tool to foster global citizenship. This programme uses the unique perspective of our planet from space as a pale blue dot to teach primary school children about climate change, solidarity and excite them about STEAM.

KEYWORDS Development, SDGs, Education, OAD, Sustainability, Entrepreneurship

OAD

#433

West African Regional Office of Astronomy for Development: The Journey So Far

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The West African Regional of Office of Astronomy for Development (WAROAD) was established in 2015 with the regional node at the Center for Basic Space Science, Nsukka. So far, 11 countries within the West and Central Africa have identified with it. Each country has a coordinator who oversees the activities therein. Since its establishment, the OAD has sponsored 21 projects in West Africa through its annual call for proposals, targeting audiences in more than 16 countries.

Within this period also, WAROAD has successfully organized summer schools every two years for post graduate and undergraduate students in universities across the region. This school has metamorphosed to a Pan Africa school because of the number of participants from other African regional offices. Subsequently, WAROAD has collaborated with other OAD regional offices and Institutions across the globe to ensure enhanced human and material development in within its catchment area. Such as the All Sky Surveys with the Stone Edge Observatory a collaboration with the North American ROAD, Erasmus Mundus+ Mobility with the European ROAD etc.

In the coming years, WAROAD has outline to conduct a survey of Astronomers of West African origin, spearhead the formation of West African Astronomical Society and Conference, document and catalogue the astronomy heritage sites within the region among others.

KEYWORDS Astronomy, Development, West Africa, CBSS, WAROAD

OAD

#2211

Overview of Astronomy projects in Southern Africa

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The Southern African Regional Office of Astronomy for Development (SAROAD) is home to 16 countries. Most of these countries have engaged in astronomy projects that address some of the UN strategic goals. We highlight these projects and assess the impact they have on society and how they place astronomy as a tool for development.

KEYWORDS astronomy, development

OAD

#2787

The Road towards Astronomy for Development in Portuguese Speaking Countries

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In 2022 the PLOAD will celebrate 7 years of existence. In this presentation, the milestones of a successful journey will be presented. Major events and achievements and their legacy will be remembered. A highlight will be given to the Eddignton@Sundy celebration, the various teacher training events and the scholarship program currently in place. Present actions will be shared with the audience and their foreseen results reviewed, in particular the ones related to the FlagShip Program and the ones related to the celebrations of the IYSSD. Finally, the next steps will be shared with the audience in an interactive format to allow the establishment of possible cooperation efforts.

KEYWORDS PLOAD

Overview of activities of Andean Regional Office of Astronomy for development

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The Andean ROAD encompasses five countries: Bolivia, Colombia, Venezuela, Ecuador and Perú, with a common language, similar social conditions and goals for scientific and cultural development. In this contribution we review the main activities that are being conducted by the Andean ROAD, as well as results of the main projects that are currently in progress.

KEYWORDS

OAD

#3046

Astronomy for Development in CLMV and Beyond

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SEA-ROAD has developed a toolkit of astronomy for development in Cambodia, Laos, Myanmar and Vietnam (CLMV) and beyond by introducing the model once successfully applied in Thailand. This toolkit includes distribution of educational materials translated into Laotian language to the Ministry of Education and Sports for further propagation, allocation of 10-inch Dobsonian telescopes to schools and National University of Laos, consultation for the construction of Laos' first planetarium and observatory, and capacity building for teachers, students, educators and public outreach officers. This toolkit shall be tailored to suit the needs of Myanmar, Cambodia and Timor Leste as well. Apart from CLMV countries and Southeast Asian region, SEA-ROAD is also reaching out to Bhutan and Botswana, giving consultations on the establishment of planetaria and observatories in the countries. Furthermore, SEA-ROAD takes inclusivity seriously by working closely with the hearing-impaired community in Thailand, collecting astronomical terms in Thai sign language and publishing its first edition in 2021. The said model shall be included in the toolkit and deployed to CLMV and beyond as a platform of astronomy for development for the years to come.

KEYWORDS

OAD

#3047

IAU South West and Central Asia ROAD: Recent Activities

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The IAU South West Asia (SWA) ROAD was established in 2015 as a collaboration of Armenia, Georgia and Iran and later on, in 2017, it was renamed to IAU South West and Central Asia (SWCA) ROAD, when Kazakhstan and Tajikistan joined. In the same year, 2017, Turkey also joined and SWCA now has 6 member countries, as well as it is open for all other countries in the region. SWCA ROAD has three directions of work: Task Force 1 (TF1) "Universities and Research" (Professional Astronomy), TF2 "Children and Schools" (Astronomical Education) and TF3 "Public Outreach". We have run several projects, including those related to Astro and Scientific Tourism in Armenia and in the whole region. SWCA ROAD is active in organization of symposia, conferences, workshops, schools and many other events, both scientific and educational/public. This year in September we plan an International Conference on "Space Research and Technologies" and 8th Byurakan International Summer School (8BISS) for Young Astronomers.

KEYWORDS

OAD

#3048

Reaching for the Stars with the North American Regional Office of Astronomy for Development

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[4]-, Northwestern University & The Adler Planetarium, United States of America

The International Astronomical Union (IAU) North American Regional Office of Astronomy for Development (NA-ROAD) is a collaboration that includes the Adler Planetarium in Chicago, IL, Associated Universities, Inc. (AUI) in Washington, D.C., Association of Universities for Research in Astronomy (AURA) in Washington, DC, Geneva Lake Astrophysics and STEAM, (GLAS Education) in Williams Bay, WI, and the Office of Astronomy for Development in Cape Town, South Africa. The NA-ROAD is working to use the power of astronomy to facilitate economic, social, and educational development across North America including the United States and U.S. Territories, Canada, Mexico, Greenland, and the island nations of the Caribbean. NA-ROAD efforts target five specific areas: 1) astronomy for science diplomacy through collaborative activities that bridge across countries and cultures, 2) use of astronomy and astronomy facilities/resources to support economic development in local communities, 3) use astronomy to facilitate STEM interest, education and outreach, 4) the use of astronomy to promote STEM interest, careers and employment for incarcerated individuals, and 5) advance collaboration and sharing of astronomical knowledges to support the general well-being of Indigenous communities and peoples. Come learn about this new initiative and how you can engage with the NA-ROAD.

KEYWORDS

OAD

#2642

Overview of the IAU fundraising efforts

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The mission of the International Astronomical Union, as the worldwide organisation of professional astronomers, is to promote and safeguard astronomy in all its aspects through international cooperation. This includes research, communication and development. One of the key activities of the IAU is the use of astronomy for development and capacity building. The IAU together with the South African National Research Foundation has created the Office of Astronomy for Development (OAD), which has 11 regional nodes and language expertise centres based around the world. Through the OAD and its regional representations, astronomy is used to impact the United Nations Sustainable Development Goals (SDGs).

The IAU's fundraising group has led the implementation of the IAU's fundraising efforts worldwide, especially for the OAD. Objectives included developing a fundraising strategy in line with the IAU 2020-2030 Strategic Plan, supporting the IAU President with approaches for fundraising as well as identifying suitable funding opportunities, developing fundraising literature and building capacity for fundraising across the astronomy community. Overall, even given the complications caused by the COVID-19 pandemic, these goals have largely been met thanks in combination to the support from the IAU President and building foundations for approaches to current and select new donors.

KEYWORDS Fundraising, Development, SDGs

OAD

#3049

Collaborations and partnerships within and outside IAU

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In this talk, we examine the past and present partnerships that have forged the growth and development of the Office of Astronomy for Development, and use these to reflect on potential ways to enhance collaborations within and outside the IAU. We discuss how strategic future partnerships could shape the IAU and its offices, especially in terms of cross-disciplinary interactions, using principles embedded in the OAD's Collaboration Gateway.

KEYWORDS

OAD

#2737

Astronomy for Environmental protection activity for EA-ROAD

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This talk about regional activities and OAD funded projects in Mongolia and region.

There was a teacher training OAD project in 2019. This project allowed schoolteachers to learn and improve their knowledge about astronomy and science teaching. The project also made many outreach activities for schoolteachers and kids and the general public in remote (nomads) areas. This project contributed to development of science technology and education in Mongolia. The project promoted lifelong learning opportunities for schoolteachers and allowed nomads to develop astrotourism in their region. Second OAD project "Environmental protection in the Gobi region using astronomical outreach activities completed successfully in 2021. Before the project activity, mining people in the local area had less information about clear dark sky protection. They have no idea how astronomical outreach can be an excellent tool for protecting the dark sky. It was the biggest developmental challenge for our project. This project made people in Gobi understand that mining can lead to environmental degradation, loss of biodiversity, increased prominence of diseases, and dust storms if it is managed poorly. If mining is managed responsibly, mining can create jobs, facilitate income, economic development, and lead to improved quality of lifestyle in Gobi. International communities such as EA-ROAD/EA-LOAD and Galileo Teacher Training, NAOJ, NASE and international astronomers were involved in this project to achieve our goals. Dust storms are the biggest environmental issue in our region. In the future our EA-ROAD will have activity on Astronomy for environmental issues such as dust storms.

KEYWORDS environmental, protection, dust, storms, astrotourism

OAD

#2309

City of Stars; A Silk Road 21st century Project

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The Silk Road passed a long way from eastern Asia to the western Europe. In the road we can pass many different countries with different cultures. The goal is that using culture and astronomy to make a connection between these cultures.

The “city of stars” project is about making a network between one city in each country using the same latitudes from east to west so by meaning that people in these cities can see the exact and the same sky. Using this network now they can share their culture and idea about astronomy in their cultures and they will be able to share what they learn in their own countries and in this way countries can connect together.

KEYWORDS Astronomy, Peace, Sky, Silk Road, Culture, Education

e-Talks

OAD

#2970

Efforts for inter-Korean Cooperation in Astronomy and the Future of Astronomy on the Korean Peninsula

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The two Koreas share a long history of astronomy and have diverse and numerous astronomical assets. Their joint assets include over 2,000 years-long astronomical observational records, observatories, various historical instruments, and star-charts, etc. Since the division of Korea, however, joint research using the assets of historical astronomy as well as general academic exchange have been severed for the last eight decades. Against this backdrop, we built international networks to ponder ways of inter-Korean astronomical cooperation and compared astronomical terms from both sides over the past several years, in an effort to facilitate exchange and cooperation in astronomy between the two Koreas. Furthermore, we are carrying out fundamental research to promote inter-Korean academic exchange in this field. In order to further expand the areas of cooperation from historical astronomy to diverse fields such as optical and radio astronomy, we are planning for the establishment of a joint observatory. In this presentation, we will introduce the efforts made to date and future plans for inter-Korean astronomical cooperation, asking for kind attention and support from international academia for the bright future of astronomy on the Korean peninsula.

KEYWORDS Inter-Korean cooperation, Korean peninsula, astronomical cooperation

OAD

#2934

OruMbya - Casa da Tia Ciata as ambassador of human rights and of cultural and scientific dissemination

Graci Mary Moreira da Silva[1]

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Between 1795 and 1811 in Riode Janeiro around one million African enslaved people arrived. They arrived at Cais do Valongo. The Cais do Valongo are now a UNESCO world heritage site and the Municipal Camera of Rio de Janeiro is now promoting activities to fight racism and promote culture, aiming at joining the safeguard of the immaterial cultural heritage with the economical sustainable development of the central region of Rio de Janeiro, where the Cais do Valongo reside, known as Little Africa.

Tia Ciata is a fundamental figure not only for samba but for all the afro-brazilian culture and she is becoming a national symbol of resistance, peace and fraternity. At the beginning of 1900 she actuated in the little Africa region carrying out educational and social projects to help and sustain poor people, often of African heritage, The NGO Casa da Tia Ciata keep promoting her same values through cultural activities, as classes of dance, drums, makulele, capoeira and much more. Recently, the NGO started a collaboration with the Observatory of Valongo, located in the same central region, in a IAU/OAD funded project OruMbya. In this talk, I will present the new development of this collaboration, which aims at focusing on women inclusion in science and the development of environmental projects. I will present the project ' OruMbya - MulhERESdo mundo sócio-cultural-tecnológico', funded by the Garotas STEM project, a collaboration between the Museu do Amanhã (RJ) and the British Museum. I will also discuss the new possibilities created by the Municipal Camera of Rio de Janeiro which has selected Casa da Tia Ciata as a member of the committee for protection and development of the Cais do Valongo. Casa da Tia Ciata also aims at promoting international collaboration, focused on social justice and ecological projects.

KEYWORDS outreach, SDGs, education, women in sciencs

OAD

#2900

RECA mentorship program: connecting and empowering the undergraduate student community in Colombia

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[12]Department of Physics, University of California, United States of America
[13]Observatorio Astronómico, Universidad Nacional de Colombia, Colombia
[14]Systems & Computing Engineer, Microsoft, Colombia
[15]Vera Rubin Observatory, Princeton University, United States of America

Astronomy career mentorship has a significant impact on early-career students, particularly those from developing countries. However, in these countries mentorship programs are absent. In this talk, we will present the first mentorship program that was conducted during August 2020-June 2021 for Colombian undergraduate students interested in pursuing a scientific career in astronomy. The program worked with 26 undergraduate students from various regions in Colombia who were paired with 26 Colombian mentors (PhD students, postdocs and faculty members) from several scientific institutions around the world and according to their academic interests. For both mentors and mentees, the gender balance was ~50% female and ~50% male. Twelve (out of the 25 students) have submitted applications to graduate schools in Astronomy outside of Colombia obtaining ten graduate scholarships so far. The remaining 11 students are expected to apply in 2022 and 2 decided to choose a different career path. In addition to one-to-one mentorship sessions, we also created eight panels focused on common questions that students might have before applying to graduate programs, i.e. documentation, financial support, academic system in Astronomy around the world, as well as the possibilities of transitioning to the industry. These panels were recorded and are publicly available for the Spanish speaking community on our Youtube channel and website. Moreover in the website, we also publicly keep updated a database with information and resources regarding graduate programs and scholarships in Astronomy available for Latinamerican students. Our program significantly increased the communication among members of the Colombian astronomical community allowing the creation of new programs, such as the research internship program for Colombian students (RECA internship program).

KEYWORDS Education, Community building, Mentorship, Skill development

OYA
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OYA

#761

The 5-decade long International Schoold for Young Astronomers program under observation

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The International School for Young Astronomers (ISYA) is a program started in 1967 by the IAU in order to aid the development of astronomy graduate students around the world, targeting specifically astronomically underdeveloped countries and isolated groups. Within its 55 years of existence, it has organized 42 schools in 27 countries. Schools usually have ~30-50 students aided by a team of 10-15 lecturers for a 3-week long intensive and broad-scope program. Over time, ISYAs have hosted nearly 1500 students and 400 lectures.

The ISYA program is evaluated in the context of the experienced gathered in the field. We highlight the impact of the program on developing countries throughout its history, the typical trajectories of attended alumni which develop professional astronomy careers and the overall impact of the program perceived by alumni at different stages of their career.

KEYWORDS Graduate School, ISYA, OYA, Education

OYA

#1361

My experience in the International School for Young Astronomer

Monica Rubio[1]

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Attending The International School for Young Astronomers in Canary Island and meeting many young astronomers was a decisive and important opportunity on my decision to becamoe a profesional astronomer. I will be most happy to share my experience and promote the attendance and participation of the young astromers in the IAU ISYA.

KEYWORDS young astronomers, experience, international

OYA

#2296

ISYA 1992 and my career in astronomy

Xiaohui Fan[1]

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I participated ISYA in 1992 in Beijing. It was my very first exposure to the international astronomical community and a milestone event in my professional and personal developments. I will reflect on my experience as a student during the success of ISYA 1992, and its many impacts in my subsequent astronomical career. In 2019, I returned to ISYA as a lecturer. I will also comment on my thought about ISYA's continuing roles in today's astronomical community.

KEYWORDS ISYA, astronomical education

OYA

#2321

The learned lessons from ISYA

Somaya Saad[1]

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I would like to express my great pleasure to talk about the activities of the Astronomical Union and the Office of Young Astronomers. I also like to share with you the lessons learned through my participation in ISYA 1994 as a student and later in ISYA 2018 as a co-organizer.

In addition to many of the beautiful memories that these participations brought us, it is also carried many important messages. Among the most important messages I have received are first : faith, self-confidence, training in dealing and caring by others.

Second: Promoting the concept of impartiality towards gender, color or race, and this is one of the most important policies of the International Astronomical Union through which the lofty goals of equality, diversity and inclusion can be acheived.

Third: I learned that youth = the future, so we have to support and encourage the youth all over the world, especially in the developing countries, by ptrovide them with chances to learn and acquire skills that will be very useful for a good start to their scientific and practical life that may help improve their societies.

KEYWORDS ISYA, OYA, IAU

OYA

#2921

Reflection on the 1999 International School for Young Astronomers and its Impact on Personal and Professional life

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The International School for Young Astronomers (ISYA) is arguably one of the most notable programmes of the International Astronomical Union (IAU) for the younger generation. The management of the programme over the years has resulted in a pool of astronomers from many nations of the world. The school has been successful in providing the much needed (theoretical and practical) exposure in Astronomy and Astrophysics to many graduate students from developing countries. A description of personal reflections from the (1999) ISYA held at Bucharest Romania is presented. In particular, resulting spin-offs from the school which impacted in personal (and national) development initiatives are highlighted. In addition, a number of lessons from the ISYA exposure will be discussed with emphasis on suggestions for more effective post ISYA participation.

KEYWORDS ISYA, Young Astronomers

OYA

#1009

The Challenges and Possibilities of a Science Career: Lessons from Nature

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Nature Careers is committed to supporting scientists around the world, especially early-career researchers who are working to find their place. We have a mission to document the challenges faced by PhD students and postdocs as they navigate the system. Through surveys and interviews, we've heard directly from thousands of scientists all over the world. They tell us about their love of science, but they also share their concerns, their disappointments, and their hopes for change.

I share some key findings from recent Nature surveys and I identify the lessons for researchers and their institutions. Much can be done to improve the career prospects and working conditions of scientists. We just need to listen.

KEYWORDS Nature, careers, surveys, ECR, challenges, discrimination, academia

OYA

#1226

Challenges faced by Latin American astronomy students

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Nationals of developing countries in astronomy, both in their home country and abroad, are constantly exposed to structural barriers throughout their careers in astronomy. This is a major reason behind the unequal participation in astronomy, a widely recognized problem, and whose consequences also affect the astronomical community as a whole. Although it is evidenced at all stages of an astronomer's pathway, it is especially critical in graduate school, since PhD and MSc programs are the transition between the training and professional stage. The first step in the process of addressing these obstacles is to identify them, therefore, this talk focuses on the challenges faced by Latin American astronomy students with the aim of fostering discussion and solutions around the topic. I will discuss challenges of several origins: (i) early education, whose issues negatively impact the transition from undergraduate to graduate programs; (ii) state of astronomy at the national level, which limits the impact of the student's activities at the international level; (iii) socio-economic conditions, that critically influence not only access but also the continuity of astronomy education; and (iv) career development opportunities, whose limited availability places students at a disadvantage when competing for positions. I will illustrate these points based on the experiences of Latin American fellows in the community, and some of the initiatives currently addressing solutions.

KEYWORDS Interdisciplinary astronomy, Structural barriers, Developing countries, Underrepresented minorities

OYA

#1592

Challenges for African's Women in Science

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African’s women scientists face different influences like Family, marriage and culture which stall their progress in the area of science, technology and innovation. In tertiary education, only a small number of researchers pursue higher education than men and women academics are a small minority. This has resulted in the worrying under-representation of women scientists in Africa. About 2.4 per cent of the world’s scientists are from Africa, with women representing only 30 percent of the continental figure. The UN must acknowledge that women participation in innovation, science and technology is essential for the sustainable development expected to be accomplished by the year of 2030.

KEYWORDS African's women, STEM

OYA

#1211

Challenges facing PhD students in astronomy: A practical experience

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Astronomy is the most exciting study that explores the universe for the betterment of humankind.

In order to both socially and economically fully benefit from astronomy, it has to involve serious strategies that include training of skilled personells, investment in both ground-and space based telescopes, satelites as well as ground based astronomical infrastructure. In so doing, the entire space science, technology and applications will be well attained and develop multidisciplinary research in areas such as space, remote sensing, security, defence, aviation, health, communication, agriculture, meteorology, astrotourism, natural resources, STEM disciplines and the like. However, limited resources including financial and the absence/weak space science policy and agencies in most countries especially developing countries, lead to the shortage of experts and investment in astronomy and related fields such as astrophysics. Under such and similar circumstances, students purcuing PhD and other levels in astronomy, face difficulties that include not having skilled personells for supervision, relaying on entirely remote supervisions by abroad experts, lacking other skills including observational skills due to lack of related laboratories and observatories. In addition, during schooling they may lack basic content for the field and this may in turn result to producing graduates who may have low ability to continue supervising or traing others in their respective areas. This may affect core functions of their academic institutions including teaching, research, consultancy, innovationa as well as strengthening of local and international collaboration. It is therefore important for every one in the field including astronomy agencies and organizations such as IAU, AOD, AfSAS and the like to continue promoting on the role of astronomy and related fields in socio-economic development as per the UN SDGs. In addition, strong local and international collaborations should be given much attention in order to trengthen students and staff exchage programs, curriculum/programs sharing among institutions as well as writing funded projects which will help in sponsoring young astronomers of both gender, females and males. Both governmental and NGOs organizations should be emphasized on investing in astronomy fields

KEYWORDS Astronomy, challenges, PhD, Practical, experiences

OYA

#1263

Challenges of PhD students nowadays

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Worldwide the varying but low completion rate of doctorates and usually longer than expected time taken in this process raises some serious questions on the research system. For successful completion of PhD the responsibilities are shared by the student, supervisor, and their institute. Although the nature and percentage of responsibilities shared by these three are different, if anyone of them does not understand and fulfill his responsibilities well it can affect the whole PhD process significantly.

PhD students face several challenges during their journey. Some challenges are typical throughout the globe while others are more pronounced in specific regions, times and fields. For example available funding and research opportunities vary tremendously around the globe also among disciplines and fields. Developing countries are now realizing the significance of astronomy and astrophysics and trying to progress in these fields, however; the major focus and funding is on other fields like sustainable development.

The unprecedented times of COVID-19 created problems that were not experienced before by PhD students throughout the globe. All the academic activities were suspended except online classes through diverse array of meeting platforms. However, some PhD students felt that online methods fall short of allowing them to pursue their research due to no experiments in labs and no observations at observatories. In several cases plans were changed to continue the ongoing PhD research or extensions were given.

During COVID-19 crisis it is observed that developing countries have cut their education budget to spend more on health protection which resulted in prominent decline in available fundings and research grants for their PhD students. Further several developed countries which are international student hubs have cancelled scholarships and internships to prevent the widespread of COVID-19 variants. This situation has made PhD more challenging for students in developing countries nowadays. Globally urgent action is needed to support the disrupted PhDs and safeguard funding and scholarship opportunities for new generation of PhD students.

KEYWORDS PhD Challenges, Affect of COVID-19 on PhD Research, PhD in developing countries, Affect of COVID-19 on PhD grants and scholarships, Low PhD completion rate, PhD student, supervisor and their institute, Astronomy and Astrophysics in developing countries

OYA

#627

The School model for the Office for Young Astronomers: Challenges perceived from within the IAU

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Educational activities are one of the essential tasks of the Union. The International School for Young Astronomers (ISYA) is a project established in 1967, which is still ongoing.

This School is inserted among other educational activities developed by the IAU through the dedicated Offices: Office of Astronomy for Education (OAE), Office for Astronomy Outreach(OAO). The Office which runs the ISYA program is the Office for Young Astronomers (OYA).

Since 10 years the Digital Technology has transformed and restructured traditional models of higher education changing radically the landscape of the learning at the ISYA level.

In this context we will discuss how the current challenges for the ISYA are perceived by the IAU.

KEYWORDS education

OYA

#2959

Astronomy Education Studies in the ISYA programs

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This work aims to suggest the inclusion of studies on Astronomy education in ISYA programs.

The basic Astronomy content is necessary and important, but we can go beyond, because as many students can learn didactics and even choose a research career in astronomy education.

Content, Pedagogical and Curricular knowledge aim at the training and performance of teachers in schools and even teachers and astronomers in universities.

Initially, we will present suggestions for inserting different teaching methodologies into the ISYA program, models of continuing teacher education, interdisciplinarity and transdisciplinarity.

About research and studies in Astronomy education, we will present different methodological and theoretical frameworks, about which it is important for students to know to continue with MSc e PhD degree, publish papers and works in meetings.

So, we hope to contribute to future careers, studies and research on Astronomy education.

KEYWORDS Astronomy, Education, Teaching methodologies, Training of teachers, Methodological framework, Theoretical framework, Research

e-Posters

OYA

#2471

Iranian Students and young amature astronomer; activities and experiences

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Astronomy is one of the big interests of Iranian students and there is a big motion of activities in astronomy in Iranian students and youngers. After twenty years of a very organized activities in schools and students, Iranian Teachers Astronomy Union (ITAU) with the help of Students has started a very huge community in the world. Students' International Network for Astronomy (SINA) came out from the activities of Iranian students.

This is a proposal and report of the activities and experiences of students in Iran about astronomy and environment to show how they were able to start something bigger. Astronomy education contains many students and girls are the most active which shows the success of involving them into astronomy education and prepare them to be looking forward to their dreams.

KEYWORDS students, astronomers, girls, education

OAE
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OAE

#1859

Astronomy Education at CSIRO – What is the Role of a National Organisation?

Robert Hollow[1]

[1]*Space & Astronomy, CSIRO, Australia*

CSIRO is Australia's National Science Agency with over 5,000 staff working on a wide range of research areas.

The Space and Astronomy unit operates radio telescopes, deep space communication and earth observation facilities in addition to astrophysics research and technology development. It runs education programs such as the PULSE@Parkes program for high school students where they use the 64m Parkes radio telescope, Murriyang, remotely and live to observe pulsars then analyse their data. Other projects include teacher training sessions, a space careers online resource plus observatory visitor centres that host over 100,000 visitors each year. More broadly CSIRO Education and Outreach runs a diverse range of programs nationally reaching hundreds of thousands of students. Examples include the Virtual Work Experience Program giving students across the country, including those in rural and remote regions to engage in meaningful career awareness and the environmental education GLOBE program developed by NASA.

Using some of these programs as examples, the role of national organisations and major institutions is discussed with both successes and challenges addressed. Opportunities for engaging with students, teachers and the public are highlighted. Organisations have a responsibility to be actively engaged with education communities. Such involvement can include acting as a trusted advisor, a source of research, data and activities and the provision of personnel. Some suggestions and recommendations for how organisations can make a positive impact in education are presented.

KEYWORDS astronomy, education, students, outreach, CSIRO

OAE

#2703

Advocating for Astronomy Education in Nepal

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Nepal Astronomical Society (NASO) has been working for Astronomy Outreach and Education since 2007 in Nepal. During these years, it has gathered handful of experiences to take astronomy into the school and university classrooms. This paper will share the challenges we faced during our activities at schools and colleges and lessons we learnt. It will also share our approach to lobby with the government to provide more space for the astronomical contents and organizations in the national curricula and textbooks. We will mainly focus on our activities related to high school students, teachers and the curricula. Also, we will share our future perspective to foster astronomy education in Nepal. It will share how we are infusing astronomy in the STEAM approach for the teaching-learning practices through our teacher training program in Nepal.

KEYWORDS Astronomy Education, Curricula, Nepal, Teacher Training, STEAM Education

OAE

#2433

Nurturing Excellence in Astronomy at School Level

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At school level, most of the students have a natural curiosity towards astronomy. As elicited in IAU-OAE's objectives, this curiosity can be leveraged to attract the general student populace towards STEM fields and to cultivate their scientific thinking process. However, more narrowly, this natural curiosity can be channeled to attract some of the best young minds to the formal study of astronomy in itself, thus contributing to the pool of the next generation of astronomers.

Astronomy problem competitions at the high school level have been serving this purpose for the last several decades. These competitions have created a rich pool of resources including reference materials, problem sets, recorded lectures and more, all accessible at the high school level. Collectively, these competitions also reach more than half a million students globally each year, making them the biggest annual astronomy education initiative by far. Let us look at the processes of these competitions and the wisdom they have gained through years of practice to emulate their best practices in other Astronomy Education projects of IAU-OAE.

KEYWORDS Excellence, Competitions, High School

OAE
#1227

An Astronomical Observatory in Djebel Orbata (Gafsa): A proposal for an academic project in Tunisia

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Tunisia is one of the countries where Astronomy and Astrophysics courses are absent in the Tunisian universities, including higher, secondary, and primary schools. Astronomy in Tunisia is only taught as a small chapter in physics and geology courses, besides its significant impact on our world from technology development to economic growth, and society advancing by constantly pushing for instruments, processes, and software that are beyond our current capabilities including advances in imaging and communications.

Nowadays, thanks to the hard work of the astronomical association and club in Tunisia and the important role that outreach activities play in sensitizing people about the importance of astronomy in sciences and the education quality, many people have been interested to continue their studies and research in astronomy, physics and space science. Although we have focused mainly on technology and knowledge transfer, perhaps the most important contribution is still the fact that astronomy makes us aware of how we fit into the vast Universe. Astronomy is at the forefront of science and technology. It is a discipline that opens our eyes, gives context to our place in the Universe, and can reshape how we see the world.

Through this proposal of an Astronomical Observatory in Djebel Orbata (Gafsa), we are suggesting collaborative work between the Tunisian Ministries/Universities and international astronomical communities and any institute that have experience in such a project to realize an astronomical observatory that links astronomical committees in Tunisia and outboard and help to build the first academic Observatory, dedicated for sciences and astronomy education. The main objective of the Astronomical Observatory in Djebel Orbata is to implement astronomy courses in Universities and schools, giving the opportunities for students to continue their research projects and study astronomy and astrophysics. Another objective of this project is to consolidate the relationship between the national and international astronomical groups and open a new channel for future collaborative projects, especially since Tunisia conserves a good dark sky with low light pollution, which will allow many astronomers to enjoy the sky quality.

KEYWORDS Tunisia, Observatory, Astronomy, Education

OAE

#2789

Digital Education and Inclusion Leading the New Trends in Education

Rosa Doran[1]

[1]N/A, NUCLIO, Portugal

Innovation in Education is a big word. Currently, the European Commission is heavily investing in the digital competence profile of citizens in general (DigiComp 2022). Various countries are adopting the use of the SELFIE and CHECK-IN tools to support schools, educators and learners to assess their digital competence profiles. Several challenges emerge from such initiatives. While self-evaluation tools can be an important step for the definition of a strong development plan, lack of support frequently hinders the desired and designed future. This presentation will target concrete actions that greatly support a whole school's engagement in innovation in education. How to integrate student-centred methodologies in classroom practices, how to transform the curricula into something that is relevant for students and how to facilitate the improvement of learners' competence profile while assuming the role of change-makers in their communities. Inclusion, differentiation, personalisation, accessibility and innovative assessment will be the main focus of this presentation.

KEYWORDS Innovation, Digital Skills, Inclusion, Differentiation

OAE

#1436

A spreadsheet based tool to analyse astronomy content in textbooks

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The middle school textbooks in many curricula around the world include a small portion of astronomy content. Most of this content is a collection of factoids and explanations of some observable phenomena, placing little emphasis on the process or nature of science. The quantum of astronomy portion covered varies across different Educational Boards even within India. The objective of the study undertaken is to develop a framework for the evaluation of content on various parameters ranging from students/teachers comprehensibility to enabling scientific as well as critical discourse in the classroom and a spreadsheet based evaluation tool to enable consistent evaluation across boards. Using this any astronomy related concept introduced at middle school level textbooks can be reviewed for the completeness of textual content, illustrations, problem/activities and enable comparison across the educational boards.

We will present our methodology for the development of the tool, discuss the rationale behind the design choices and report how the tool stands up to trial analysis of 3 sample curricula from India.

KEYWORDS Middle School Curriculum, Astronomy Content, Content Analysis, Analysis Tools

OAE

#3422

OAE Node Korea : Our past and future

Jungjoo Sohn[1]

[1]Earth Science Education, Korea National University of Education, Republic of Korea

Education & Public Outreach committee (EPO) of the Korean Astronomical Society(KAS) is doing the mission of OAE Node. EPO's work has been focused on participating in the construction of the national science curriculum, leading outreach activities both in domestic and overseas. OAE Node Korea is proposing following contributions: (1) reflecting astronomy community input in national curriculum, (2) developing educational resources for teacher training, and (3) developing diverse formats of activity. The workforce are diverse in terms of affiliation like universities, secondary schools, research institute and science center, therefore we expect synergy between different institutions in fostering astronomy education. In this talk, we will introduce several core activities, and describe our plan as OAE Node; We intend to develop education materials, and continuously explore effective shoring methods with neighboring countries.

KEYWORDS

OAE

#2147

Development plane for Astronomy Education in Frame Work OAE –Egypt Center

Abd El Fady Morcos[1]

[1]*Astronomy, NRIAG, Egypt*

The IAU OAE works towards the goal of creating a community of astronomers, astronomy education researchers and education practitioners. OAE –Egypt Center starts the first step in high-quality astronomy teaching resources. The working group of the center start to examine the national school curricula to improve it, to be suitable as an Arabic references for teaching astronomy not only in Egypt but also for the surrounding Arab countries. Planning to perform training courses for the science teachers about the methodology of teaching physics. Using the available facilities of Kottamia observatory, Center of Scientific Excellency and other available abilities helping in putting special school curricula utilize the full potential of including topics from astronomy in STEM teaching and on life syles

KEYWORDS OAE, IAU, Education

e-Posters

OAE

#3212

Science teachers' mental model changes through a modeling-based teacher training program about galaxies and cosmology

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The purpose of this study is to develop a teacher training program about galaxies and cosmology using modeling-based approach, and to evaluate the effectiveness of the program by comparing changes in the program participants' mental models. The developed program consists of four sessions on core ideas in the field of galaxies and cosmology, in which participants are asked to resolve given modeling tasks by cooperation with other participants. The program is applied to a small group of three in-service science teachers who majored in earth science education and is currently working in secondary schools. To analyze the mental models of the participants before and after the program application, participants are asked to answer pre- and post-test questions designed for this study. In addition, information on their teaching experience, view of teaching, knowledge in astronomy are collected through in-depth interviews. As a result, we present mental models in three topics: (1) classification of galaxies and active galaxies, (2) expansion of the Universe, and (3) cosmology models. The participants have experienced numerous linguistic interactions while working on the subjects, which help to elaborate, systemize, and integrate reasoning structure of the explanatory system. The final mental models show that the modeling-based training program, when applied to a small group of teachers, is effective not only in forming consistent system of explanation but also in acqualing complex teaching knowledge.

KEYWORDS teacher training, modeling, mental model, system of explanation, galaxies and cosmology

Astronomy for All
Busan 2022

XXXIst General Assembly
International Astronomical Union

IAUGA 2022

ABSTRACTS

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ECWG 1

Astronomy for Equity and Inclusion

Invited & Contributed Talks

WG 1

#2960

Astronomy for Equity, Diversity and Inclusion - a roadmap to action within the framework of the IAU centennial anniversary

Lina Canas[1]

[1]*IAU Office for Astronomy Outreach, IAU/NAOJ, Japan*

From 12-15 November 2019, the IAU Symposium on “Astronomy for Equity, Diversity and Inclusion - a roadmap to action within the framework of the IAU centennial anniversary” was held in Japan, welcoming 124 participants from 31 countries. Co-organised by the National Astronomical Observatory of Japan (NAOJ), Japan, and the Korea Astronomy and Space Science Institute (KASI), South Korea, the IAU symposium aimed to create a people-centred strategy for action to improve inclusion and diversity in astronomy. The conference hosted four keynote sessions, 57 talks and 37 posters; four Shared Spaces, one Safe Space and two special sessions dedicated to the conference’s outcomes. The themes addressed focused on Identifying and Addressing a Climate of Inclusivity; Sustainable Development Goals (SDGs): Gender Equality and Its Intersections, Astronomy for Society — Inclusion, Diversity, Equity, and Empathy in Communicating Astronomy; Diversity in Research: Identity, Ethnicity and Culture in Research Teams; and Research, Outreach, Education for Inclusion. As a special satellite event, this IAU meeting also hosted the IAU100 Global Project Inspiring Stars, an IAU exhibition that showcases a wide variety of resources to support inclusiveness. Here we will present the strategy of implementation, challenges and outcomes of the symposium.

KEYWORDS inclusion, diversity, equity

WG 1
#2139

Diversity, Equity, & Inclusion in Large Collaborations: A Decade of Work in the Sloan Digital Sky Survey-IV

Rachael Beaton[1]

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Since the inception of the fourth phase of the Sloan Digital Sky Survey (SDSS-IV), a committee has existed to address diversity, equity, and inclusion (DEI) in the collaboration. In its current form, this committee is known as the Committee on Inclusiveness in SDSS (COINS) and serves to understand and to address DEI concerns in SDSS-IV. COINS uses a number of means to understand concerns of the collaboration, but chief amongst them is our bi-annual Demographic Survey. The founding concern for COINS was aimed at addressing the representation of women in all facets of SDSS, but particularly in their representation in management and leadership roles. I will present data that demonstrates improvement on these axes over the term of SDSS-IV. Expanding beyond this central concern, I will also discuss other demographic axes including cultural/ethnic/nationality diversity and socio-economic indicators. Because SDSS includes 60 institutions on five continents, we also have to understand how differences in national-level and institutional-level science culture manifest in the work of the collaboration. This limits both our ability to collect data on some problems (because of jargon differences in higher education), articulate the problems in a way that facilitates adequate solutions, and ultimately makes it difficult to make progress within the collaboration for all issues. I will show our existing DEI documents attempting to normalize behavior/participation in scientific activities (available on github) and also articulate the remaining challenges.

KEYWORDS Diversity, Equity, Inclusion, Large Surveys

WG 1

#2777

AstroAccess: Advancing research on accessibility to prepare for diverse needs in human spaceflight activities

Anna Voelker[1], Caitlin O'Brien[2]

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[2]*Astronomy, Ohio State University, United States of America*

On October 17th, 2021, Mission: AstroAccess successfully launched twelve Ambassadors with mobility, vision, and hearing disabilities on a historic ZERO-G parabolic flight, as the first step in a progression toward flying a diverse range of people to space. This group consisted of disabled scientists, veterans, students, athletes, and artists. During this flight, the Ambassadors experienced lunar, martian, and zero-gravity while conducting a series of demonstrations to investigate the ways in which space vehicles and habitats can be made more accessible.

In May 2022, a second ZERO-G flight will take place in order to expand upon this research. This IAU session will feature the findings of both flights and inspire the participants to rethink diversity, equity, and inclusion as essential priorities that benefit not only marginalized individuals, but space science and humanity as a whole. Mission: AstroAccess is dedicated to advancing disability inclusion in space by incorporating the principles of universal design into future spaceflight activities. Session participants will learn about the ways in which modifications made for disabled space researchers can enhance system safety and efficiency for everyone.

Astronomers and space scientists have a critical role to play in the transformation of space access. Mission: AstroAccess aims to redefine not only who gets to research space, but who gets to go it, but uniting disability advocates, astrophysicists, accessibility experts, and space industry leaders. Access to space changes the worldview not only of aspiring explorers, but of those that employ them, and most importantly, those that look up to them. By generating new opportunities for disabled scientists to succeed and by providing equity activists a platform, we have the power to inspire the next generation of scientists and world-changers.This session will provide an exciting look at the future of disability inclusion in space and invite you to take part.

KEYWORDS Accessibility, Disability, Diversity, Inclusion, AstroAccess, Spaceflight, Parabolic flights

WG 1

#395

Let's go to the Universe, TOGETHER! - with Hearing-impaired children

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[2]*Solar and space weather, Korea Astronomy and Space science Institute, Republic of Korea*
[3]*Education, Nowon cosmos space center, Republic of Korea*

'Let's go to the Universe TOGETHER!' is one of outreach program in Universe Awareness(UNAWE) Korea since 2018. This program is the astronomy- and space-related activities. The high-school students can participate as the volunteers and educators. 1st, each team should submit their application with own activity adea. Next, selected teams can join the program : 3 times education by astronomers or educators and 1 time volunteer activity.

In 2019, COVID-19 attacked the earth. This program should stop, either. Nevertheless, we needed outreach for children. In 2021 winter, we were be able to restart 'Let's go to the Universe, TOGEHTER!'. Especially, hearing-impaired children joined to us. However, we didn't need a sign language. The children are the hearing-impaired children using a cochlear implant or hearing aid. In fact, ~3% and ~88% of hearing-impaired people use a sign and spoken languages in Korea, respectively. This information could learn from one of the lectures of this program. Definitely, the high-school volunteers should take the understanding class of impairment.

The goal of this program is more friendly and equity astronomy for all. We hope the high-school volunteers are not only to learn new knowledges but also to deliver their understandings and the participated children have a dream and hope for their future, especially for astronomy and space science.

This was good lesson to perform the astronomy and space science education program for impaired people. 1st, we should know what they need. Most able-bodied people cannot understand the impairment. Therefore, we should learn and study what we can give them. 2nd, we should check what they interested in. Especially, the children have lots of imagination. The impaired kids are same. We should give a chance they have a dream. In this program, most participants told us that they joined in this kind of program first time because they don't have enough time to have a chance in various fields. They have spent most time to learn the language for rehabilitating.

According to this program, not only we learn how to prepare outreach program for impaired people, but also we gave hearing-impaired children a chance and possibility to enter to astronomy and space science fields. Finally, We hope they can dream a various area as well as a rehabilitation.

KEYWORDS outreach, education, volunteer, astronomy, space science, hearing-impairment, UNAWE

WG 1

#3438

Astronomy breaks barriers and connects people

Santiago Vargas Domínguez[1]

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Astronomy is one of the most inspiring activities touching the life of human beings for millennia. Contributions of astronomy, not only scientific developments but also related to cultural aspects of uncountable societies, make it reasonable to think about it as the perfect tool to contribute to setting diversity and inclusion goals nowadays. In this talk I will present some experiences aiming at promoting inclusion by using astronomy, generating opportunities to demonstrate the multiple connections between cultural traditions, astronomical knowledge, reconciliation, and many others, boosted by a fascination with the sky.

KEYWORDS

WG 1

#3436

HERITAGE, INDIGENOUS PEOPLES, AND ASTRONOMY

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[2]Archaeoastronomy and Cultural Astronomy, Universidad Nacional Autónoma de Honduras, Honduras

The use and appropriation of common spaces, public spaces, and indigenous lands has become frequent and normalized, unfortunately this is also true for Astronomy, Astrophysics and Space Sciences. In this presentation, the indigenous concerns and social movements regarding sacred lands and astronomical facilities that have been built upon them will be highlighted. The joint IAU/RAS/AAS Committee on Culturally Sensitive Sites will be discussed along with its main objectives, and its activities so far. The first efforts are two-fold: first, to make astronomers better aware of such sensitivities and how they may best be addressed and next how such empathy can better bond science and culture.

The aim of this joint initiative is to open astronomical science to broader perspectives, the role of native societies in preserving humanity's astronomical heritage, and indeed how astronomy can play a decisive role as an open discipline in the development of science and inclusivity worldwide. Research, education, and outreach in Astronomy and Astrophysics must do its part. We all live under one sky.

KEYWORDS

WG 1

#2341

"Working at the Intersection of Art, Science, and Culture for the Benefit of All"

Annette Lee[1]

[1]*SFIS, Arizona State University, United States of America*

Stars are many things, to many people, but we can all agree that there are few experiences that bring to the surface such feelings of joy, curiosity, and excitement as gazing upwards on a dark night sky. Instinctively, we seem to know that the same sky has shined down us, on all humanity, for all time. The sky defines our humanness and connects us through the millennia past, present, and future. We truly share one sky.

Right now, human beings are enduring many overlapping crises…the Covid-19 pandemic, political unrest in Eastern Europe, global climate crisis, forever chemicals, gene editing, space colonization, inequities in education…It is very easy to be overwhelmed. As leaders at this time and particularly in STEM education, it is critically important to recognize this as a time of transition. We remember that we all share responsibility as individuals and as members of a society as we are forced to rethink our very identities and are challenged to create an improved version of 'normal'. At this time of post-Industrialization, consumer culture, and globalization, it is important to remember that from an Indigenous perspective, we are all interconnected.

Of importance is to build an interdisciplinary group that brings together educators within the astronomy community and beyond that have been engaged with these issues, priorities, and communities. This presentation is to introduce the Native Skywatchers research and programming initiative, to report on recent activities, and to invite participation by those that are invested in these issues. The path forward can only be forged by recognizing the past and acting for our future. Einstein himself said "we cannot solve our problems with the same thinking we used when we created them".

KEYWORDS Indigenous, Diversity, Transformative change, Inclusion, Two-eyed Seeing, Astronomy education, Culture

WG 1

#3437

Discrimination, bullying and harassment in STEM

Simona Mei[1], Dayna Thompson[2]

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[2]Department of Physics & Astronomy, Charles W. Brown Planetarium, Ball State University, United States of America

In any community, there is unfortunately the chance for discrimination, bullying, harassment, and so on. This is why the group "Management of Diversity and Inclusion in Large International Collaborations" from the International Astronomical Union is collecting stories and instances from the Science, Technology, Engineering, and Mathematics (STEM) community surrounding diversity, equity, and inclusion. It is our hope that by speaking up about how #ItHappensInSTEM, the community can promote awareness and help bring about structural change.

KEYWORDS

WG 1

#2938

Think Over the Barriers: EDI in Astronomy in the Netherlands, Europe, and Internationally

Jake Noel-Storr[1]

[1]SSE / Kapteyn Astronomical Institute, Rijksuniversitet Groningen, Netherlands

I will discuss EDI on a local, national, continental, and international scale from my own connections to all of those communities,m including how to get involved, how to build community, and what equity looks like instead of inclusion.

KEYWORDS Diversity, Equity, Inclusion

WG 1

#2705

The Supernova Foundation -- Mentoring young women on the path to a career in Physics and Astrophysics

Karin Menendez-Delmestre[1], Natalia Vale Asari[2], Michelle Lochner[3], Ghazal Geshnizjan[4], Valeria Pettorino[5], Narusha Isaacs[6], Supernova Foundation[7]

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[3]Astronomy, University of Western Cape / South African Radio Astronomy Observatory, South Africa
[4]Applied Mathematics, University of Waterloo, Canada
[5]Astronomy, CEA, Paris-Saclay, France
[6]Astronomy, Centre for Radio Cosmology, University of Western Cape, South Africa
[7]The Supernova Foundation, The Supernova Foundation, South Africa

The lack of equal opportunities in Science, Technology, Engineering and Mathematics (STEM) at higher levels within the academic context is a reality in most countries. The expression "leaky pipeline" refers to the observation that in each "step" of the academic/professional career, there is a preferential loss of people who do not fit the "typical" image of a scientist. One of the most affected groups is that of women. In the last years, the STEM community has explored actions to counter this trend; mentoring is one of them. Studies demonstrate that there is a greater retention of female STEM students in the early years of academic training when they establish close mentoring contact with a female scientist.

The Supernova Foundation, founded in 2017, is an excellent example of such mentoring efforts. It is an international program that seeks to encourage and support women and gender minorities who wish to pursue careers in physics and astronomy. It is designed to connect undergraduate/graduate students from around the world with more experienced female (astro)physicists. In a nutshell, the Supernova Foundation aims to provide one-to-one mentorship for women students as they transition to postgraduate studies. It also effectively connects and provides a support network across the globe at different stages of their career. Additionally, mentors and mentees organize webinars with useful advice and interesting discussions on career choices, application process, CVs, work-life balance and gender-specific harassment.

The Supernova Foundation has grown over the years and, today, it rounds up ~240 mentees and ~100 mentors from a total of 53 countries. We would like to invite all young students who are women or self-identify as women to come and take advantage of this great online community. The Supernova Foundation is also looking for more mentors, so this is a shout-out to those of you already established within your careers and are committed to a more inclusive and diverse STEM community.

KEYWORDS mentoring, women, international, online community

ECWG 2

Global Coordination of Ground and Space Astrophysics

Invited & Contributed Talks

WG 2

#2336

Synergies of ground- and space-astronomy

Ewine Van Dishoeck[1]

[1]Leiden Observatory, Leiden University, Netherlands

The big science questions in astronomy require a multiwavelength, multimessenger and multidisciplinary approach to address them. This brief talk will give a number of examples of synergies between ground and space-based telescopes, ranging from the early days of gamma ray burst observations to modern day exoplanet, gravitational wave and cosmology studies. Two categories of synergies can be distinguished. The first category contains facilities that need each other to reach the scientific goals of the mission. The second category includes cases where ground and space observatories strengthen each other but where good science can also be done standalone. How can the IAU promote such synergies? It provides a neutral forum to bring various parties together, which is most effective at an early stage. Suggestions for future such discussions are welcomed.

KEYWORDS Space astronomy, Telescopes, Multiwavelength astronomy, Multimessenger astronomy

WG 2

#654

Global coordination of stellar and stellar population spectroscopy in current and future spectroscopic surveys

Scott Trager[1], **Sara Lucatello**[2], **Amata Mercurio**[3]

[1]*Kapteyn Astronomical Institute, University of Groningen, Netherlands*
[2]*Osservatorio Astronomico di Padova, INAF, Italy*
[3]*Osservatorio Astronomico di Capodimonte, INAF, Italy*

The current and coming generations of all-hemisphere spectroscopic surveys -- e.g., Gaia, SDSS-V, GALAH, H3, DESI, WEAVE, 4MOST, MOONS, PFS, Euclid, and more -- will result in a wealth of spectra of both stars and galaxies. However, these vast spectroscopic catalogues run the serious risk of being inconsistent with each other if careful cross-survey calibration is not put in place now. I will describe the efforts currently underway to coordinate astrophysical calibration for stars -- stellar atmospheric parameters and radial velocities -- and galaxies -- redshifts, velocity dispersions, emission and/or absorption line strengths, etc. -- across several ground-based spectroscopic surveys, and where cross-survey calibration efforts should be oriented in the future.

KEYWORDS catalogs, surveys, stars: abundances, stars: atmospheres, galaxies: general

ECWG 3

Junior Members

Invited & Contributed Talks

WG 3

#2421

Scientific Writing for Astronomers: Choice of journal, Submission process, and Writing guide

Johan Knapen[1]

[1]*Research, Instituto de Astrofisica de Canarias, Spain*

This contribution is the second part of a mini-workshop, "Scientific Writing for Astronomers", to be delivered with Dr Nushkia Chamba, during the ECWG3 meeting and will focus on important aspects of publishing in astronomy, including the choice of journal and the submission process. We will consider how to identify the journal that best fits your manuscript, how to choose your co-authors, and how to identify yourself uniquely and appropriately in the scientific literature. We will also discuss the roles of referee, scientific editor, and language editor in the publishing process. In a second part of this contribution, we will introduce how you can use writing to maximise the impact of your paper, by considering aspects such as the title and abstract, the figures and tables, and the various sections, from introduction to conclusions, acknowledgements and references. If time allows, selected aspects on how to use the English language to best express your ideas will be included.

KEYWORDS Science Writing, Training, Mentoring, Young astronomers

WG 3

#2631

Scientific Writing for Astronomers: From Thinking to Paper Outline

Nushkia Chamba[1]

[1]Astronomy, Stockholm University/Oskar Klein Center, Sweden

While scientific writing is one of the main ways astronomers publish and share their research to the broader community, most researchers never receive any training to learn and develop this skill. This contribution is the first part of a mini-workshop, "Scientific Writing for Astronomers", to be delivered with Prof. Johan Knapen, during the ECWG3 meeting. We will introduce and discuss the goals of the workshop in an interactive manner. We will then focus on the first steps towards writing a scientific article, creating a paper outline even before beginning to write sentences or paragraphs. Issues such as how to identify which papers in the literature are most relevant to a study and why "critical thinking" is important when approaching the task of scientific writing will also be addressed.

KEYWORDS scientific writing, publishing

WG 3
#2907

IAU Outreach: Building Bridges Through Communication and International Cooperation

Lina Canas[1]

[1]*IAU Office for Astronomy Outreach, IAU/NAOJ, Japan*

Through the IAU Office for Astronomy Outreach (OAO), the IAU engages the public in astronomy through access to astronomical information and communication of the science of astronomy. The OAO work focuses on building bridges between the IAU and the global astronomy community of outreach professionals, educators, amateur and professional astronomers, and the public. Through international cooperation, we envision making astronomy a science accessible to all. This talk will feature IAU's outreach initiatives and OAO's ten-year legacy, implemented in collaboration with the IAU National Outreach Coordinators (NOCs) present in over 120 countries worldwide. With the IAU Strategic Plan for this decade, the IAU has envisioned several actions regarding communication, outreach, and public engagement. In this talk will highlight the importance of collaborating with the IAU members and the contributions that the IAU community can bring to implement the IAU Strategic Plan successfully.

KEYWORDS IAU Outreach, IAU Strategic Plan, IAU Communications

WG 3

#2261

Writing grant proposals: Your road to success

Richard de Grijs[1]

[1]*School of Mathematical and Physical Sciences, Macquarie University, Australia*

Writing grant proposals is a never-ending aspect of the professional scientist's commitments. Writing good proposals takes time, dedication and a clear vision of the expected outcomes of one's research. In this training session, we will cover the differences between research paper and grant proposal writing, with particular emphasis on the grant funnel; how to frame your proposal and convince reviewers of your expertise; how to ensure that your proposal supports the conceptual framework at the basis of your research; and how to convey your project's potential impact and benefits. Above all, we will emphasise the golden rule: Think audience!

KEYWORDS funding, proposals, grants, training, audience, methodology

WG 3

#2639

Writing grant and observing proposals: sharing my ESO and ERC experience

Vincenzo Mainieri[1]

[1]PSD, ESO, Germany

I will share the experience accumulated over many years of writing observing proposals (mostly ESO but not only) and grant proposal (mostly ERC but not only).

While it is impossible to have a recipe that would work universally, there are for sure some specific suggestions that could be helpful for our younger colleagues.

KEYWORDS

ECWG 4
Women in Astronomy

Invited & Contributed Talks

WG 4

#2337

Women in astronomy and the IAU: past, present and future

Ewine Van Dishoeck[1]

[1] *Leiden Observatory, Leiden University, Netherlands*

A brief overview of the growing role of women in the IAU over the past century will be presented, including actions by the IAU to enhance the fraction and visibility of women. To stimulate further improvements, statistics are crucially important. The IAU collects statistics of the fraction of female members (both regular and junior) for each country which are summarized at https://www.iau.org/administration/membership/individual/distribution/. To illustrate trends among the younger generation, a summary of career statistics of more than 500 PhD students since 2000 in the Netherlands (a country with a significant international PhD program covering more than 30 different nationalities) will be presented.

KEYWORDS Women in Astronomy, Statistics, PhD students

WG 4

#2495

Women participation in Latin America astronomy

Silvia Torres-Peimbert[1]

[1]*Instituto de Astronomia, Universidad Nacional Autonoma de Mexico, Mexico*

Only through great efforts it has been possible to gradually achieve recognition for women scientists around the world. The discipline of astronomy is no exception. In this work I intend to present not only statistics but to comment about the achievements that women astronomers in Latin America have obtained. As expected, the case study that I am most acquainted with is that of Mexico, which I propose to enlarge to comprise the whole area.

KEYWORDS women, sociology, equity

WG 4

#3132

Career stories, problems, and efforts in India to achieve gender balance in Astronomy

Annapurni Subramaniam[1]

[1]*Astrophysics, Indian Institute of Astrophysics, India*

India, like any other nation, lags behind and strives to create gender balance in STEM, including Astronomy. As a woman scientist and heading an organization in India, I shall discuss some of the initiatives taken towards, awareness, sensitization, policies as well as initiatives toward gender balance in astronomy. Based on my experience, I will share some of my thoughts on how Institutions can create a friendly environment and gender balance.

KEYWORDS

STI Indicators and the Design of the 2022 Edition of Women and Girls In Astronomy IAU Global Outreach Project

Suzana Filipecki Martins[1]

[1]OAO, IAU OAO, Japan

Since 2019 the IAU Global Outreach Project Women and Girls in Astronomy takes place annually between the International Day of Women and Girls in Science on 11 February and the International Women's Day on 8 March with the aim of promoting the inclusive advancement of astronomy. The IAU Office for Astronomy Outreach (OAO) set two overarching goals for the 2022 edition: a) to challenge perceptions, attitudes, behaviours, social norms and stereotypes towards women in Astronomy, and b) to foment the uptake of astronomy by girls.

The design of the project activities was guided by the findings of the "Gender Gap in Science" project and by UNESCO's STI gender indicators (SAGA project). There were interviews that promoted the visibility of women in leadership positions within the astronomical field. Shared videos highlighted diverse profiles of women in astronomy, sharing different role models and promoting astronomy as a viable vocation for girls and young women. The role of women in astronomy was further addressed through social media posts featuring historical female astronomers. The online campaign also promoted outreach events, astronomy inclusion projects and outreach activities, and by doing so strived to mainstream gender perspectives in astronomy outreach. Lastly, in cooperation with the Women in Astronomy WG, the project put forward the "Draw an Astronomer Contest", where children sent a visual representation of how they imagine astronomers look like. The contest promoted awareness of non-conscious and cultural gender biases observed even in young children.

Although many challenges continued from previous editions, namely the engagement of the male astronomy community, the 2022 edition of Women and Girls in Astronomy saw an increase in various project KIPs, including the number of outreach events highlighted and online engagement. Lessons learned provide a roadmap on how to embed gender perspectives in IAU OAO's outreach projects and programmes – all year round.

KEYWORDS

WG 4

#1439

Gender balance in CBK PAN

Jolanta Nastula[1]

[1]ZGP, CBK PAN, Poland

Space Research Centre of the Polish Academy of Sciences (CBK PAN) is an interdisciplinary research institute operating within the 3rd Department of the Polish Academy of Sciences. CBK PAN conducts scientific and technical work in the field of space physics as well as physical and geodynamic research of planets and the Earth. The distinguishing feature of the Center is combining research and construction activities: we design and build space devices, as well as analyse the data obtained with their help. The CBK PAN employs both women and men in scientific and administrative positions. In this presentation we will show the present gender balance in the Institute.

KEYWORDS Gender

WG 4

#1060

IAU Women in Astronomy Working Group and activities

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The gender and diversity dimension of science and technology has become one of the most important and debated issues worldwide, impacting society at every level. The International Astronomical Union, through its Executive Committee Working Group on Women in Astronomy, has been a strong advocate for discussing these themes openly and for supporting initiatives that can improve a more balanced representation of diversity in our community.

The IAU Women in Astronomy (WiA) Working Group (WG)'s mandate is to collect information, propose measures, and initiate actions in support of, or to advance equality of opportunity for achievement between women and men in astronomy, in the IAU, and the world at large. It has 192 members as of now from all continents and we look forward to welcoming many more members from all over the world.

In this talk, I will provide an overview of IAU WiA WG activities as well results of the recent survey on 'Working Conditions of Women in Astronomy' and the efforts being carried out by the WiA WG Organizing committee members.

KEYWORDS IAU members, Gender balance, Women in Astronomy, surveys, factors affecting women career in Astronomy

WG 4

#3134

Women in Astronomy division of Korean Astronomical Society

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In 2016, the Women-in-Astronomy (WiA) division of the Korean Astronomical Society was established to promote exchanges among female astronomers and to establish strategies and action plans to achieve true equality for women. In order to raise awareness of the underrepresentation of women in leadership positions, such as executive committee, board of directors, and division chairs, within the Korean Astronomical Society and to expand the participation of female astronomers in the Korean Astronomical Society, various activities have been organized by the WiA over the past six years. I will introduce those activities and changes achieved by them.

KEYWORDS

ANU Research School of Astronomy and Astrophysics Advanced Instrumentation Technology Centre (AITC) women-only recruitment strategy and objectives?

Tony Travouillon[1]

[1]Advanced Instrumentation and Technology Centre, The Australian National University, Australia

The Advanced Instrumentation and Technology Centre (AITC) is the instrumentation wing of the Australian National University's (ANU) school of astronomy. The centre conducts technical work to produce the next generation of instruments for ground-based astronomy with an increasing footprint in related fields including space and communication technologies. The centre consists of over 40 people with a mix of engineers, scientists, students and administrative staff. Over the years, it has been challenging to attract and retain female applicants, notably to some of the more technical roles which has led to a poor gender balance. In this presentation, we will present our new hiring strategy to lead to a long-lasting gender balance.

KEYWORDS

WG 4

#3449

ERC Measures and Practices to Improve Gender Balance in Science

Eleni Chatzichristou[1]

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In recent years, there has been important effort by institutions and funding agencies to improve the gender balance in science. This is especially true for ERC: from creating awareness about ERC grants to the signing of grant agreements, all processes are carefully designed to ensure equal opportunities for female and male scientists. A dedicated working group was set up in recent years to monitor gender balance in ERC calls, and a Gender Equality Plan endorsed by the ERC Scientific Council, was established since the 7th Framework programme and has been regularly updated. The fruits of these efforts are encouraging: the percentages of female applicants and grantees have been constantly increasing since FP7, through H2020, to Horizon Europe. In fact, the success rates of female/male applicants in most types of grants have almost reached equality in the last two years.

KEYWORDS

WG 4

#526

Empowering Women through Training and Skill Development

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The Women in Astronomy Working Group started a new initiative on Training and Skill Development for Women. Skill development programs aim to enhance the ability of women and extend support groups by providing proper guidance, infrastructure, interactions and encouragement. I shalll present the data of the two Training Programs held in November 2021 and January 2022 to discuss the key issues, participation and outcomes of these programs. These programs covered important areas like python, astropy, overleaf, ADS, virtual observatory tools like TopCat, ESASky, etc. Interactive Social Media groups help continue the interaction and sustain the progress of participants. Data on the program to be held in April will also be presented. It is hoped that this initiation will help in improving data analysis skills and awareness amongst young and early career researchers as well as those interested in updating their skills.

KEYWORDS Women, Training, Skills, Software

WG 4

#1237

How does gender equality benefit men?

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Gender inequalities have historically prevented many women to access knowledge, being able to show their full potential, and developing in many different aspects of their personal and professional lives.

Although there are increasing interest and initiatives to promote gender equality, still many people think that it is something that advantages women at the cost of men and that strategies to address some of the issues related to gender equality do not take men into account.

In this talk I will put some ideas on the reasons men should care about gender equality, adding more inputs to highlight the importance of talking about it but also to implement actions towards gender equality in our daily actions, and in our academic communities. Men should promote gender equality because it is fair to do so, but ultimately, men will also benefit from it.

KEYWORDS Gender equality, Women, Men, Academic, Actions

WG 4

#559

Challenges for young women astronomers in South Korea to continue their careers based on statistical surveys

Suhyun Shin[1]

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I will introduce how young women in South Korea have grown up to be the key players of society in Korea's social, cultural, and economic background, and will present common difficulties they have faced to maintain their roles in our society based on various statistical surveys. The college enrollment rate of women has overtaken that of men since 2005, however, the employment rate for women in their 30s is ~26% lower than that of men in 2019. The difference in South Korea (~26%) is huge in comparison to those of Europe (~13%), the U.S. (~15%), and the OECD (~20%). 58.2 % and 43.3 % of women with permanent positions take maternity leave and parental leave, respectively, whereas 6.6 % and 1.8 % of women with temporary positions use these leaves in 2019. About 30% of married women natural scientists in their 30s have halted their careers due to pregnancy, childbirth, and childcare in 2020, implying the existence of the glass ceiling. In this talk, I examine the current state of young women astronomers in South Korea, understand problems they have encountered, and suggest possible solutions to alleviate the challenges through getting insight from statistical surveys provided by South Korea and the OECD.

KEYWORDS Young women astronomers in South Korea, The glass ceiling, Statistical surveys

WG 4

#2666

ASTROMINAS: Empowering girls through science

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A collective founded in 2019, ASTROMINAS was conceived by women from the Institute of Astronomy, Geophysics and Atmospheric Sciences and other exact sciences institutes at the University of São Paulo, located in southeastern of Brazil. Based on an innovative approach, with online classes, lectures and group dynamics throughout Brazil, it managed to reach in its 2 editions, held in 2020 and 2021, 1200 girls from different cultures, ethnicities and regions of the country. The main objective was to facilitate the access of young students of basic education to the university, strengthening their contact with women scientists and enabling the development of skills that involve scientific work. In this way, it aimed at the empowerment and feeling of belonging of these girls in scientific areas, helping to demystify the structural idealism of the absence of women in these areas and aiming towards gender equality. The central subject is astronomy which, due to its highly interdisciplinary profile, was a great tool for young students to expand their knowledge in several areas of natural sciences, mathematics and technology. To make possible reaching so many places and minds, the team of organizers was composed of more than two hundred volunteer scientists, at different academic moments, who dedicated their time to become the Fairy Godmothers of the participants, allowing them to see within the scientific environment and project their future at the university. A new edition is being organized this year and the main motivation remains: to bring new brilliant minds to science.

KEYWORDS girls in science, basic education, gender identity

WG 4

#1275

Work opportunities and the study of the female presence in astronomy and space sciences in Tunisia

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Tunisia is one of the North African countries, where culture, tradition, and society still play an important role in females' lives, careers, and futures. The conservative and the "closed culture" of some countries have been always a very sensitive topic to discuss and highlight. Although the religious, cultural, traditional, and even geographic barriers, Tunisian females scientist achieved their dreams and reached their goals and objectives, displaying to the world the capabilities of any woman to overpassing any obstacles and life challenges.

In this work, we will share the situation of females in sciences and in particular in astronomy, astrophysics, and space sciences, in Tunisia, and highlight the diverse difficulties that women and girls can face in life, proceeding with their careers and research. We will present previous experiences of successful female stories and present the projects that are dedicated to supporting women in sciences and astronomy.

KEYWORDS Tunisia, Female, Astronomy, difficulties, gender, equality

WG 4

#807

Career challenges, problems, and consequences in the Middle east

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Women's participation in STEM (Science, Technology, Engineering, and Mathematics) is a major concern in Middle East countries. As a result of education and economic change, the influence of Arab women in national and regional affairs is growing rapidly. Although the area`s patriarchal ideology remains in place, social practices, i.e. social, cultural, health, and gender issues, are challenging it. These social practices, visible in the workplace, the home, the courts, the political arena, and the religious sphere, are forcing men, women, and other family members to reconsider women's role, status, and leadership potential in this century. We present in this study, consideration of the social, cultural, and gender challenges faced by young women pursuing STEM careers and recommendations that could help the female students, community, and government to support these women in overcoming these obstacles, including gender-balance statistics.

KEYWORDS STEM, Middle East, Challenging, Arab Women

Iranian Women Astrobomers

Encieh Erfani[1]

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As a founder of the Iranian Women Astrnomers' group, I will explain the situation of women astronomers in Iran, their activities and their challenges.

KEYWORDS Women Astronomers, Iran

WG 4

#3136

A case study of gender inclusiveness in the Development in Africa with Radio Astronomy (DARA) Big Data programme

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The Development in Africa with Radio Astronomy (DARA) Big Data programme represents a human capacity development intervention looking to increase Africa's research and skills base in data-driven science and associated technologies needed for dealing with extremely large data sets. DARA Big Data was established in 2017 and builds on the skills required for the Square Kilometre Array (SKA) telescope.

The hosting of the mid-frequency array of the SKA in Africa provides an opportunity to develop a broad range of skilled professionals, which includes skills linked to high performance computing, data analytics and big data technologies, amongst others. Many of these skillsets are transferable across research domains and speaks to the need for the development of multidisciplinary skills in moving into the Fourth Industrial Revolution (4IR). The DARA Big Data programme builds on this aspect of transferability of skills across sectors with training initiatives applied to a range of thematic areas including astronomy, health and agriculture. Initiatives forming part of DARA Big Data includes skills development workshops, schools and hackathons, as well as graduate scholarships in data science intensive research within these thematic areas.

To determine the existing gender gap in training and development initiatives forming part of DARA Big Data, and potential factors contributing to the gender gap, a case study of the programme was undertaken by the South African Radio Astronomy Observatory (SARAO). The findings from the case study highlight the need for targeted interventions that can be implemented at programme, institutional and policy level to ensure women's participation in capacity development opportunities linked to the 4IR. In this talk, the findings from the DARA Big Data case study will be presented, which will give more insight into the programme's inclusion of women and challenges faced by African women in taking up training and development opportunities.

KEYWORDS

e-Posters

WG 4

#2706

The Supernova Foundation – Mentoring young women on the path to a career in Physics and Astrophysics

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The lack of equal opportunities in Science, Technology, Engineering and Mathematics (STEM) at higher levels within the academic context is a reality in most countries. The expression "leaky pipeline" refers to the observation that in each "step" of the academic/professional career, there is a preferential loss of people who do not fit the "typical" image of a scientist. One of the most affected groups is that of women. In the last years, the STEM community has explored actions to counter this trend; mentoring is one of them. Studies demonstrate that there is a greater retention of female STEM students in the early years of academic training when they establish close mentoring contact with a female scientist.

The Supernova Foundation, founded in 2017, is an excellent example of such mentoring efforts. It is an international program that seeks to encourage and support women and gender minorities who wish to pursue careers in physics and astronomy. It is designed to connect undergraduate/graduate students from around the world with more experienced female (astro)physicists. In a nutshell, the Supernova Foundation aims to provide one-to-one mentorship for women students as they transition to postgraduate studies. It also effectively connects and provides a support network across the globe at different stages of their career. Additionally, mentors and mentees organize webinars with useful advice and interesting discussions on career choices, application process, CVs, work-life balance and gender-specific harassment.

The Supernova Foundation has grown over the years and, today, it rounds up ~240 mentees and ~100 mentors from a total of 53 countries. We would like to invite all young students who are women or self-identify as women to come and take advantage of this great online community. The Supernova Foundation is also looking for more mentors, so this is a shout-out to those of you already established within your careers and are committed to a more inclusive and diverse STEM community.

KEYWORDS women, mentoring, international, online community

ECWG 5

Professional-Amateur Relations in Astronomy

Invited & Contributed Talks

WG 5

Interest in Pro-Amateur Collaboration in Astronomy: What do professionals and amateurs have to say?

Tim Spuck

USA

In May of 2021 the IAU Pro-Am Working Group was formed. Its initial focus was to explore interest and opportunities for collaboration between IAU professional astronomers and amateurs from around the world. To this end, the Pro-Am Working Group commissioned a survey and collected responses between mid-December through February 2022. Survey respondents included 250 professional astronomers and more than 1000 amateur astronomers. Results indicate strong interest in pro-am collaboration by both professionals and amateurs, and further identified key areas of interest. In this presentation we will share the survey results and highlight key findings.

Meet the IAU Astronomers! Programme

Suzana Martins[1], Lina Canas[2]

Netherlands[1], Portugal[2], Japan[1, 2]

The "Meet the IAU Astronomers!" programme connects teachers, informal educators and amateur astronomer groups with IAU-members for meet-ups (events) where professional astronomers have the chance to share their research, the importance of astronomy for society, and why following astronomy as a career is a viable and rewarding choice. The Meet the IAU Astronomers! programme responds to Goal 4 of the IAU Strategic Plan 2020-2030, that is: to "facilitate international communication through exchanges" and "encourage communication of science and critical thinking through IAU member public engagement". A relaunch in spring 2022 was set to align the programme objectives and event structure with new evaluation instruments, and to provide astronomers with tools that allow them to deliver inclusive events. Shared with participating astronomers through a comprehensive handbook, the proposed structure and methodology widen the scope of the events, conceiving them to transcend the astronomer research area and strive to create lasting personal and social impact on the communities, participants and the astronomers themselves. For example, understand that the event should challenge non-conscious biases and broaden the spectrum of role models. The handbook also encourages astronomers to consciously incorporate inclusive outreach practices, and strategies that will encourage critical thinking, for example by including opportunities for participants to identify, analyse, and evaluate the content shared. In this presentation, we will introduce the programme and describe best practices gathered from other projects such as STEM Ambassadors that reflect inclusive practices and inform the Meet the IAU Astronomers!

WG 5

The amateur astronomy culture in India

Aniket Sule

India

India has about a two centuries' old tradition of non-professionals engaging in astronomical observations. Presently Amateur Astronomy groups exist in most cities, but there is little inter-group communication. Most groups engage in outreach and education activities, However, a few groups and a handful of individuals take up serious projects. In this talk, I will present an overview of the present amateur astronomy scene in India.

Amateur astronomers in Korea

In-Ok Song, So Weol Lee

Korea

The Korean Amateur Astronomical Society was established in 1991 and has a history of about 30 years. It is active in the distribution, education, and exchange of amateur astronomy nationwide. Major activities include training astronomical instructors, student astronomical observation contests, amateur astronomer festivals, Messier marathons, and various education and volunteer activities related to astronomical observation activities. As of 2021, it has produced about 2,000 astronomical instructors and has grown to 16 nationwide and local branches. The Korea Astronomy and Space Science Institute, a national research institute, has supported astronomical instructor qualifications and star camps. Local professional astronomers contribute to talks at events or training courses occasionally. The Korean Astronomical Society has an education and a public relations committee, and close exchange is expected in the future to promote such research collaborations and workshops.

WG 5

The Starlight network and the need for ProAm cooperation for local sustainable development through Astro-tourism

Antonia Varela

Spain

The Starlight Reserves, Tourist Destinations and other modalities are scenarios that incorporate the observation of the sky as part of the natural, scenic, cultural and scientific heritage and encourage star tourism, promoting infrastructure, products, activities and training of specialized guides in the field of sustainable tourism.

The Starlight Foundation, bearing in mind the peculiarities and the high standards of the current and future demand, has created a course for starlight monitors and guides, specialized in guiding groups during the night and the day. This courses are supported by the Institute of Astrophysics of the Canary Islands and have a great acceptance. We already have more than 800 guides and monitors of more than 16 nationalities. A high percentage of these Starlight guides and monitors are amateur astronomers who wish to become professionals in this field and find in astro-tourism an excellent employment opportunity. The Starlight Foundation also has agreements with astronomers' groups for the dissemination of astronomy, the analysis of sky quality campaigns and the promotion of Starlight certification and sky protection in the countries where it works. To be leaders in astro-tourism, it is necessary to innovate, diversify and sophisticate the offer, personalizing it in each destination and promoting the development articularly, involving public administrations, entrepreneurs clusters, local communities, scientific institutions and specialized guides (i.e. pro-am cooperation).

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General Field

#3213

Near-infrared spectroscopy of delta Scuti type variable stars

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Delta Scuti variable stars have spectral types of A0 to F5. Like many other pulsating stars, they are found in the instability strip of the Hertzsprung-Russell (H-R) diagram. Unlike most variable stars they can either be in the main sequence (MS) evolutionary phase or they may have "turned-off" the MS toward the giant-branch after depleting hydrogen fuel in the core. They pulsate in radial and non-radial modes and range in amplitude from 0.01 to above 0.3 magnitudes. In addition to pulsation, atmospheric processes such as convection, rotation, and magnetic fields can also exist within these stars. Motion, temperature, luminosity class and other characteristics can be determined by analyzing the spectra of stars. For variable stars, the spectra is key to understanding the processes behind pulsation.

Delta Scuti type stars have been studied extensively in the optical wavelengths (where the largest changes in brightness take place), but little work has been done spectroscopically in the near infrared. We have obtained spectra over the wavelength range 0.95-2.4 microns for over two dozen delta Scuti stars using the spectrograph, TripleSpec, on the ARC 3.5m telescope at Apache Point Observatory in New Mexico. We present the preliminary analysis of these data including measurements of spectral lines and temperature estimates from the continuum.

KEYWORDS Pulsating Stars, Near-infrared, Spectroscopy, delta Scuti

General Field
#2658

Measuring high-quality atomic data of astrophysical importance

Pratyush Ranjan Sen Sarma[1], Maria Teresa Belmonte[1], Santiago Mar[1]

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High-quality atomic parameters (transition probabilities, oscillator strengths, hyperfine structure constants) are essential in modelling stellar spectra and obtaining stellar parameters such as chemical abundances. However, the quantity and quality of the existing data are insufficient to satisfy current needs.

Closed after 30 years of experience in plasma diagnosis and measurement of transition probabilities and Stark widths and shifts of noble gases, the Atomic Spectroscopy Laboratory at the University of Valladolid (Spain) has now reopened with new objectives adapted to the most pressing contemporary needs: the measurement of atomic parameters (such as transition probabilities, oscillator strengths and hyperfine constants) of heavy elements with a focus on rare earths.

This poster will explain the capabilities of our laboratory in a clear way, how we obtain emission spectra of neutral, singly- and doubly-ionised atoms using a hollow cathode lamp (for heavy metals) or a highly-repetitive pulsed-discharge lamp (for gases) and how we analyse these spectra to get accurate atomic parameters. Our laboratory is equipped with a diffraction grating spectrometer based on a Czerny-Turner configuration with a holographic diffraction grating of 2400 lines/mm (resolution of 100 000 at 350 nm) and we are in the process of setting-up a Fabry-Pérot interferometer capable of resolving hyperfine structure. We can measure spectra in the range 200 – 850 nm and will collaborate with Imperial College London (UK), the National Institute of Standards and Technology (NIST) and the Lund University (Sweden) to extend our measurements to the vacuum ultraviolet and the infrared regions.

The final aim of this poster is to bring the astronomy community closer to the field of laboratory astrophysics and establish an enriching exchange of ideas between astronomers and groups working on experimental atomic physics. This will help our recently-reopened laboratory to focus our efforts on the most urgently needed data and begin new collaborations.

KEYWORDS emission spectroscopy, atomic data, laboratory astrophysics, transition probabilities, oscillator strengths

General Field

#2445

Galactic Chemical Evolution with short lived radioisotopes

Benjamin Wehmeyer[1]

[1] *CSFK, Konkoly Obs & Univ of Hertfordshire, Hungary*

In addition to the insights gained by studying the galactic evolution of chemical elements, short lived radioisotopes contain additional information on astrophysical nucleosynthesis sites.

Meteorites can carry information about the nucleosynthetic conditions in the early Solar System using short lived radioisotopes [1][2], while detections of live isotopes of cosmic origin in the deep sea crust help us understand recent nucleosynthetic processes in the Solar neighborhood [3]. We use a three dimensional, high resolution chemical evolutioncode to model the conditions at the time of the formation of the Solar System, as well as to explain why different classes of radioisotopes should often arrive conjointly on Earth, even if they were produced in different sites. Further, we included radioisotope production into a cosmological zoom-in chemodynamical simulation of a Milky Way-type galaxy, which provides a map of gamma-rays from the decay of radioactive Al-26 consistent with the observations by the INTEGRAL instrument [4].

[1] Lugaro, Ott, Kereszturi, 2018 PrPNP 102, 1L

[2] Côté et al., 2021 Science 371, 945

[3] Wallner et al., 2021 Science 372, 742W

[4] Kretschmer et al., 2013 A&A 559, A99

KEYWORDS Milky Way, Short lived radioisotopes, Chemical Evolution, Solar System

General Field

#2440

Gamma-Ray Bursts' redshift distribution depends on their duration

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Two of the Gamma-Ray Bursts' important properties are the duration and the distance of the burst. We analysed these two important quantities of the phenomena. We mapped their two-dimensional distribution and explored some suspicious areas. As it is well known the short GRBs are closer than the others, hence we search for parts in the Universe where the GRBs duration differs from the others. We also analyse whether there are any range in the duration where the redshifts are differing.

KEYWORDS gamma-ray burst: general, large-scale structure of Universe, methods: statistical, methods: data analysis

General Field

#2161

Tension seen in solar peculiar motion inferred from various cosmic dipoles including the CMB dipole

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Peculiar motion of the solar system, determined from the dipole anisotropy in the Cosmic Microwave Background (CMB), has given a velocity 370 km/s along RA=168°, Dec=-7°. Subsequent peculiar motion determinations from the number counts, sky brightness or redshift dipoles observed in large samples of distant radio galaxies and quasars yielded peculiar velocities two to ten times larger than CMB, though in all cases the directions matched with the CMB dipole. We present evidence for the tension seen in solar peculiar motion inferred from various cosmic dipoles including the CMB dipole and discuss its implications for the cosmological principle, the basic tenet of the modern cosmology.

KEYWORDS Cosmic Microwave Background, cosmological parameters, large-scale structure of Universe, Solar peculiar motion, Tension in cosmic dipoles

General Field

#2094

Interhemispheric asymmetry of the equatorial ionization anomaly (EIA) on the African sector over 3 years (2014-2016): Effects of thermospheric meridional winds

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[3]Physique, Department of Electrical and Computer Engineering, University of Illinois Urbana-Champaign, Urbana,, United States of America

Observations made by the Langmuir probes on board the Swarm satellites and the Fabry-Perot interferometer (FPI) installed at the Oukaimeden Observatory in Morocco have been systematically analyzed to study the effect of geomagnetic activity on the thermosphere-ionosphere system over 3 years. The annual variation of the electron density (Ne) shows that during the day, the ionospheric density starts to increase at mid-latitudes, with a single crest between 8 LT and 12 LT. It is also noticeable that the double crest structure is present between 12LT and 00LT: symmetric from 12 to 20 LT and asymmetric from 20 LT to 24 LT. Observations show strong seasonal variations, with the Ne being lower around the June solstice. We have noticed the semi-annual anomaly: the Ne is higher around equinox than around solstice. For solstice seasons, the asymmetries in the Ne are stronger at the December solstice than at the June solstice. For equinox seasons, we can notice equinoctial symmetry in all local time sectors, meaning that the same trend is observed for both equinoxes with or without symmetrical crests. The effect of meridional neutral winds on equatorial ionization anomaly (EIA) crests have been classified during both quiet and disturbed conditions. Over the studied region, the southward meridional winds have the tendency to enhance the northern crest of the EIA during quiet time and in a more pronounced way during geomagnetically disturbed conditions. Finally, we have quantified the relations between the thermospheric neutral winds data and the EIA by introducing an asymmetrical index.

KEYWORDS Ionosphere, Thermosphere, Fabry-Perot interferometer (FPI), Swarm satellites, Oukaimeden Observatory, geomagnetic activity

General Field

#1469

Reappraisal of Open Star Cluster NGC752 by Gaia EDR3

Alisher S. Hojaev[1], R.A. Gaysin[1]

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We present the results of deep study of the open star cluster NGC752 based on our analysis of the Gaia EDR3 data (A.G.A. Brown, et al., A&A, vol. 649, A1,2021). An angular radius of NGC752, its distance from the Sun and the age are estimated as ~ 0.5°, ~ 450 pc and 1.3–1.5 Gyr (M.A. Agüeros, et al., ApJ, vol. 862, 33 (2018), respectively, based on its known members (M. Agarwal, et al., MNRAS, vol. 502, 2582, 2021; S. Bhattacharya, et al., MNRAS, vol. 505, 1607, 2021). The ASteCA package (G.I. Perren, R.A. Vázquez, and A.E. Piatti, A&A, vol. 576, A6, 2015) was used for automated analysis of the main parameters of the cluster for statistical verification of the physical cluster true allocation from random super densities of field stars. The set of functions included in the code applies astrometric and photometric data to obtain objective precise values for the given coordinates of the cluster center, radius, luminosity function and integral value of the color index, accurate estimations of metallicity, age, redness and distance to the cluster by the isochron selection method based on the generation of synthetic cluster on the base of theoretical isochrones and the selection of the maximum match using a genetic algorithm. 44 new members of the cluster were reliably detected with a membership probability in the range from 0.81 to 1 (302 stars in total), which supplement the number of known member stars (258) within NGC 752 (M. Agarwal, et al., MNRAS, vol. 502, 2582, 2021; S. Bhattacharya, et al., MNRAS, vol. 505, 1607, 2021). We considered the stellar density profile from the center, the diagram of proper motions of the stars of the cluster NGC752 with mean values $\mu_\alpha \cos\delta$ = 9.790 mas / yr, μ_δ= -11.784 mas / yr; the comparative histogram of parallaxes of the identified probable cluster members and the field stars and the initial mass function (IMF) with cluster z(metallicity)= 0.00797± 0.00087, log(age)=9.352±0.030, distance modulus (m-M)0=8.258±0.023.

KEYWORDS open cluster, Big Data analysis, Gaia EDR3

General Field
#1461

New variables in open cluster Gulliver 35

Alisher S. Hojaev[1], R.G. Karimov[1]

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We present the preliminary results of the analysis of the light curves from TESS data combined with Gaia EDR3 data analysis for the stars in the region of open cluster Gulliver 35 in Southern Hemisphere. We aimed to search for variability of stars and perform more comprehensive study of the open cluster itself. We have discovered 70 new variable stars in the region of the studied cluster, and in 29 we have found the periodicity of brightness changes.

KEYWORDS open clusters, variable stars, Big Data analysis

General Field

#1363

Previously undiscovered exoplanets detected with deep learning

Amelia Yu[1]

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Using deep learning with the Adam optimization algorithm in this research, I detected 11 previously undiscovered exoplanets in the Kepler data. Although some of the exoplanet transit signals were evident, others were not as strong and need further evaluation. By using my own code, open source libraries, and deep learning packages such as TensorFlow and implementing the Adam algorithm as an optimizer, I developed a Python program for exoplanet detection. The program first normalizes the transit light curves, trains the deep learning model using the Adam optimizer, folds the transit light curves to intensify the transit signals, then uses the model to search for exoplanet transits in the Kepler light curves. Among the newly detected exoplanets, 9 of them are ultra-short period (USP) exoplanets with orbital periods shorter than a day, and the 2 others are short period exoplanets with periods between 1 to 10 days. Because the Kepler mission lasted for nine years and observed each star for a selected period of time, there are much more Kepler Objects of Interest (KOI) with shorter periods than those with long periods in the NASA database. This may be a reason why the orbital periods of the detected exoplanets in this study are shorter than 10 days. Meanwhile, the detection of these new exoplanets, especially the USP exoplanets, can shed light on their kind and expand our views on their planetary systems, which possess different features than our Solar System. Finally, these findings show that artificial intelligence such as deep learning can be an effective technological tool to detect objects of interest in astronomy big data.

KEYWORDS exoplanet discovery, Kepler, ultra-short period exoplanet, short period exoplanet, deep learning, TensorFlow, big data

General Field

#870

The Global Structure of the Milky Way's Stellar Halo Based on the Orbits of Local Metal-poor Stars

Genta Sato[1]

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It is known that the stellar distribution of a galaxy records the information about its formation and evolution history. We focus on the Milky Way (MW). By analyzing the global structure of the MW's stellar halo, including its dominant subcomponent, Gaia-Sausage-Enceladus (GSE), we constrain the MW's history. The method of this analysis is to employ the superposition of the stellar orbits covering the large MW's space, where each of the orbit-weighting factors is assigned following the probability that the star is located at its currently observed position. The selected local, metal-poor sample with [Fe/H] < –1, using Gaia Early Data Release 3 and Sloan Digital Sky Survey Data Release 16, shows that the global shape of the stellar halo is systematically rounder at all radii in more metal-poor ranges. This result is consistent with the scenario that the MW's flattened and relatively metal-rich structure is caused by the in-situ component, and the more spherical and more metal-poor structure corresponds to the accreted component. It is also found that the stellar halo in the relatively metal-rich range of [Fe/H] > –1.8 actually shows a peanut-like shape. Since it is known that a peanut-like halo is a trace of a major merger event (e.g. Naab et al. 2006), our result suggests that the MW had experienced such an event. For the subsample of stars showing GSE-like kinematics at [Fe/H] > –1.8, its global density distribution has an axis ratio of 0.9, which is more spherical than the general halo sample, and an outer ridge at r ~ 20 kpc. This spherical shape is consistent with the features of accreted halo components, and the ridge suggests that the orbit of GSE's progenitor had an apocenter of ~ 20 kpc. The article reporting this research is published in Sato & Chiba, 2022, ApJ, 927, 145.

KEYWORDS The Milky Way, galaxy archeology, stellar halo, metal-poor stars, Gaia-Enceladus

General Field

#290

Searching for cosmological variation in the fine-structure constant with a single quasar system

Le Duc Thong[1]

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Possible cosmological space-time variation in dimensionless physical constants such as the fine-structure constant (α= e24πε0ħc) can be tested through observational systems. Using a single H¬2 system from quasar 0347-383 spectra at zabs=3.025, our analysis yields Δα/α=(-0.02±0.72)×10-8. Current study presents the most robust constraints on the cosmic timescales variation of α to date compared with the publications in the literature.

KEYWORDS varying constants, quasar individual Q0347-383, absorption spectra analysis

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e-Talks

General Field

#3309

Sensitivity of half density ALPACA to sub-PeV gamma rays from the Galactic Center region

Yoshichika Yokoe[1]

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Andes Large area PArticle detector for Cosmic ray physics and Astronomy (ALPACA) is an air shower array experiment aiming to observe cosmic rays and gamma rays in the southern hemisphere at 100 TeV (sub-PeV) energy region. The array will cover an 83,000m2 surface area with 400 plastic scintillation counters at the plateau (4,740m a.s.l.) of the Chacaltaya mountain in Bolivia. Underground muon detectors covering 3,700 m2 in the area allow a clear identification of muon components in air showers, enabling us to discriminate between cosmic-ray initiated showers and gamma-ray initiated showers. Construction of half density ALPACA, which covers the same area of ALPACA but with 200 counters, is scheduled in 2023.

In the southern sky, the Galactic Center is a possible candidate for PeV particle accelerators, PeVatrons. Observations of sub-PeV gamma rays are essential to test the existence of PeVatrons, but so far, the energy spectrum is measured up to a few tens of TeV. The half density ALPACA is designed to have a sufficient sensitivity to test the gamma-ray emission from the Galactic Center in the sub-PeV energy range.

In this contribution, the performance of the half density ALPACA to a hypothetical gamma-ray source with the same trajectory and energy spectrum as the Galactic Center reported by H.E.S.S will be presented. The effective area, the angular and energy resolutions in the gamma-ray observations and the differential flux sensitivity after the cosmic-ray background rejection using the number of detected muons are presented., If the energy spectrum of the Galactic Center follows a power-law extrapolation from the TeV region up to the 100TeV region, more than 5 sigma detection at 100 TeV is expected after 2 years observation of the half density ALPACA.

KEYWORDS gamma-ray astronomy, the Galactic Center region

General Field

#2953

The United Arab Emirates Radio Astronomy Observatories

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To promote a radio astronomy program in the United Arab Emirates, the University of Sharjah (UoS) and the Sharjah Academy for Astronomy, Space Sciences, and Technology (SAASST) have built two small radio observatories. The first one is a "Low-frequency Radio Astronomy Observatory" that consists of two 20.1 MHz "Decametric Radio Telescope (DRT)" arrays (dual and single dipole) and a "Solar Radio Spectrometer (SRS)." The second is a 1.4 GHZ 40-m Sharjah Radio Interferometer (SRI).

Each array of the DRT system is connected to a separate 20.1 MHz receiver. The dual dipole array is intended to observe the Jupiter-Io interactions, solar bursts, and the background radio emission of the Milky Way Galaxy in winter. The single dipole array was designed to monitor solar radio bursts during summer. Solar radio bursts are easier to detect than Jupiter-Io radio bursts. We have detected more than 50 solar radio bursts and more than 20 Jupiter-Io radio bursts.

The SRI system first started installing a 5-m SPIDER 500A dish that operates at 1.4 GHz. This professional 5-m radio telescope has a straightforward visual interface, where the user has control of all the functions of the telescope. The installation of the first SPIDER 500A at SAASST considered our aim to build a 40-m radio interferometer using three SPIDER 500A dishes installed at the vertices of a rectangular scalene triangle, with distances (sides of a scalene triangle) of 30, 40, and 50 meters. This array simulates the resolution of a 40-m diameter single-dish antenna, with a collecting area equal to an antenna of 8.7 meters in diameter. The synthesized beam in this configuration measures about 0.36 degrees (21.6 arc minutes). There is an even larger extension of the 40-m radio interferometer under construction. Six more SPIDER 500A telescopes will be added to the system to build the 1-km Sharjah Very Long Baseline Interferometer (SVLBI). This new system will have an angular resolution of 0.7 arc minutes.

This paper will highlight the radio astronomy program at the University of Sharjah in light of the new radio observatories and its contribution to the MSc in Astronomy and Space Sciences and the future Ph.D. in Astrophysics.

KEYWORDS decametric, radio, solar radio-bursts, Jupiter-Io bursts

General Field

#2792

Tools for Observational Astronomy Education: The case of Nigeria

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With over 50 years of theoretical astronomy research in Nigeria, observational astronomy is still currently faced with various challenges, in particular poor funding from government and the prevailing harsh economic condition which both results to massive astronomy brain drain. In recent years, there have been a growing interest of the younger generation in astronomy, mostly through astronomy outreach programmes, workshops, summer schools that all focuses on the power visualisation in exciting the mind.The big question is how do we, in the absence of professional astronomy facilities in Nigeria, provide students with the right tools needed for observational astronomy. A viable solution, besides virtual observatory resources, are low-cost effective astronomical facilities that will be primarily used for astronomy education in tertiary institutions. Such facilities will offer students hands-on experience on the techniques used in observation planning and execution, data acquisition and analysis in a professional astronomical observatory. In this talk, I will discuss the efforts we have made so far in setting up such facilities and seek for collaborations in this regard.

KEYWORDS

General Field

#2326

Work opportunities and the study of the female presence in astronomy and space sciences in Tunisia

Rania Hamdani[1]

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Tunisia is one of the North African countries, where culture, tradition, and society still play an important role in females' lives, careers, and futures. The conservative and the "closed culture" of some countries have been always a very sensitive topic to discuss and highlight. Although the religious, cultural, traditional, and even geographic barriers, Tunisian females scientist achieved their dreams and reached their goals and objectives, displaying to the world the capabilities of any woman to overpassing any obstacles and life challenges.

In this work, we will share the situation of females in sciences and in particular in astronomy, astrophysics, and space sciences, in Tunisia, and highlight the diverse difficulties that women and girls can face in life, proceeding with their careers and research. We will present previous experiences of successful female stories and present the projects that are dedicated to supporting women in sciences and astronomy.

KEYWORDS females, scientist, astronomy, astrophysics, space sciences, experiences, successful

General Field

#2325

Astronomical heritages and facilities in Tunisia

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Dates back to around 1981, the Youth and Science Association of Tunisia (AJST) - Nabeul Club, represented by Habib Zangar, Faouzi Zaghbib, Slim Mamouri, and Henri Monreal, in collaboration with some students from the Higher National Engineering School of Tunis-ENIT, succeeded to build the first astronomical observatory in Tunisia, which is located in the coast of the Nabeul city. This astronomical observatory was mainly dedicated to outreach activities of the AJST and public events. Although the observatory was in a strategic location for public access and in close vicinity to schools and institutes, the geographic location was not very adequate, since it was close to the sea, and consequently, the building was damaged by the high humidity and the salinity of the water. A few months later, the astronomical observatory of Nabeul was closed, for safety reasons, since the building was in a bad situation and all equipment was taken away for independent use in open space, and the observatory was saved as a historical monument.

Thirty-seven years later, and in August 2018, a group of amateur astronomers from the Youth and Science Association of Tunisia- AJST, Djerba Club, directed by Lassaad Akrout, decided to build an astronomical observatory with personal funding and a local donation from citizens without any support from the governmental institutions and the concerned ministries. The Observatory is located on the roof of a Mosque, in an isolated zone, far away from light pollution under a nearly dark sky, and in an easily accessible location. The main objective of this observatory is also outreach activities in the context of the AJST events and summer schools.

Besides the astronomical observatory of Nabeul and Djerba, Tunisia owns many important organizations that hard work to sensitize the public about the importance of astronomy, astrophysics, and space sciences in the development of education quality and equal society. In this work, we will present the astronomical heritages and the facilities in Tunisia as a country in the stage of developing astronomy and space sciences with its society and join the parade of space and universe exploration.

KEYWORDS observatory, monument, astronomy, astrophysics, society, AJST, collaboration

General Field

#2322

AstroTalk project:
A new challenge within the COVID-19 pandemic

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In 2020, and within the COVID-19 pandemic and the lockdown in several countries, many persons have been suffering from isolation and the cancellation of most meetings, and in some cases the closing of schools, universities, and the prohibition of public events. During this pandemic, the NOC office in Tunisia and in collaboration with several national and international astronomical communities remoted an online project that was based on weekly online lectures for the public and amateur astronomers. This project was initiated in order to keep the science communication and the practices in communicating astronomy to your community in a very difficult time that was facing the global planet. The Astrotalk project displays the ability to communicate science and astronomy not only on a national scale but also international scale since the project was extended afterward to reach many OAOs and astronomers in diverse continents and many countries.

The Astrotalk project is still in progress, and we are aiming to reach and collaborate with all the OAO National Outreach Coordinators, to promote bridges of science communication and future projects in the near future and help connect the diverse astronomical groups over the world. Moreover, we will demonstrate the role of the AstroTalk project in providing one of the OAO objectives in linking the different NOCs and helping construct a multi-cultural and multi-aspect working environment. The project have been initiated in 2020, and it has been selected for the third Award within the Astronomy@Home Awards 2020 context it has been classified as the first Outstanding Online Event.

KEYWORDS COVID-19, Astrotalk, OAO, NOC, multi-cultural, Awards, collaboration

General Field

#2308

Shirineh: A model of the role of astronomy in sustainable development and environmental protection

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[1]*Iranian Teachers Astronomy Union (ITAU), Associate of Commission C1 WG Astronomy Education Research & Methods, Iran*
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We have tried to use the knowledge of astronomy to improve the view of teachers and students on development and to make them aware of the dangers of inaccurate and careless development of the environment, and to acquaint them with sustainable development with an emphasis on environmental protection. One of our good achievements, which can be used as a model in other areas, is the role of teachers in maintaining the (tangent shirineh)

Some people, with the permission of the government, tried to destroy this area in the form of mining, while this strait is the most important wildlife habitat of this region with its water springs and this strait is a recreation for the people of the region. Finding out by holding several meetings with teachers made them aware of the dangers of this mine, and with the help of teachers and students, they started holding observation nights and astronomy programs in each weekends, and with the help of the people, prevented mining due to their power. The financial situation of the miners and the support of the local government for the miners became very difficult for us, but the presence of teachers and students and then the local community caused a difficult battle.

This event became a permanent part of the local community under the management of teachers, who were forced to leave the area after 657 days by turning this strait into an observatory, and the people provided more employment than the miners claimed by developing tourism in the area.

Today each equinox and solstice we run public programs and other months many ancients ceremonies have runs there.

KEYWORDS Education, Environment, Society, Astronomy, Nature

General Field

#2170

Our peculiar motion from Hubble diagram of SNe Ia and implications for the Cosmological Principle

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Peculiar motion of the solar system, determined from the dipole anisotropy in the Cosmic Microwave Background (CMB), has given a velocity 370 km/s along RA=168°, Dec=-7°. Subsequent peculiar motion determinations from the number counts, sky brightness or redshift dipoles observed in large samples of distant radio galaxies and quasars yielded peculiar velocities two to ten times larger than CMB, though in all cases the directions matched with the CMB dipole. Here we introduce a novel technique for determining the peculiar motion from the magnitude-redshift (m-z) Hubble diagram of Type Ia Supernovae (SN Ia), one of the best standard candles available. We find a peculiar velocity 1600±500 km/s, about four times larger than the CMB value, along RA=173°±12°, Dec=10°±9°, the direction being within ~2σ of the CMB dipole. Since a genuine solar motion would not depend upon the method or the dataset employed, large discrepancies seen among various dipole amplitudes could imply that these dipoles, including the CMB one, might not pertain to observer's peculiar motion. However, a common direction for various dipoles might indicate a preferred direction in the universe, implying an intrinsic anisotropy, in violation of the cosmological principle, a cornerstone of the modern cosmology.

KEYWORDS supernovae Ia, Cosmic Microwave Background, cosmological parameters, Solar peculiar motion, large-scale structure of Universe, Cosmological Principle

General Field

#2201

Modeling Mass-loss Varying Luminosity: Mass-loss Varying Luminosity and its Implication to the Solar Evolution

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Several models of the L, in the evolutionary timescale, have been computed as a function of time. However, the solar ΔM, is one of the drivers of L variation in this timescale. The purpose of this study is to model L(ΔM), and to predict the luminosity variation before it leaves the main sequence. We numerically computed the ΔM up to 4.9 Gyrs from now. We used the ΔM solution to compute the modeled L(ΔM). After that, we validated our model against the current solar standard model. The L(ΔM) shows consistency up to 3.43 Gyrs. At about 4.351 Gyrs, the Sun loses 29% of its mass and its luminosity increased to 2.2L . According to the model, the total main-sequence lifetime is close to 9 Gyrs. The model accurately predicts when the Sun's central supply of hydrogen will be depleted and when it will be ready to exit the main sequence. It may also explain the Sun's fate by making some improvements over the models. Several models of the L, in the evolutionary timescale, have been computed as a function of time. However, the solar ΔM, is one of the drivers of L variation in this timescale. The purpose of this study is to model L(ΔM), and to predict the luminosity variation before it leaves the main sequence. We numerically computed the ΔM up to 4.9 Gyrs from now. We used the ΔM solution to compute the modeled L(ΔM). After that, we validated our model against the current solar standard model. The L(ΔM) shows consistency up to 3.43 Gyrs. At about 4.351 Gyrs, the Sun loses 29% of its mass and its luminosity increased to 2.2L . According to the model, the total main-sequence lifetime is close to 9 Gyrs. The model accurately predicts when the Sun's central supply of hydrogen will be depleted and when it will be ready to exit the main sequence. It may also explain the Sun's fate by making some improvements over the models.

KEYWORDS Lumonisity, Mass loss, evolution

General Field

#1593

Statistical challenges for cosmic shear in the 2020s

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Next-generation cosmic shear surveys will provide us with unprecedented constraining power on our cosmological model. However, the computational challenges posed by the size of these datasets dangerously hinder the feasibility of their analysis within a rigorous statistical framework for uncertainty propagation, such as the one provided by Bayesian inference. The plethora of contaminants affecting cosmic shear analyses, in particular, urgently calls for the development of sophisticated pipelines that can ensure a level of accuracy in the final cosmological constraints corresponding to the unprecedentedly high precision that will be provided by future datasets.

In my talk, I will review some of the major statistical challenges for future analyses of cosmic shear, including (but not limited to):
- number and resolution of simulations, and simulation-based inference;
- covariance matrix estimation;
- Gaussianity of the cosmic shear likelihood;
- Bayesian hierarchical models and advanced sampling methods;
- rigorous statistical methods for the quantification of "tensions" between datasets.

I will present strategies that are currently being developed to overcome some of these challenges, with emphasis on applications of novel Machine Learning techniques. A critical review of successes and limitations of these techniques will be presented, including examples from the most recent cosmic shear analyses from major international collaborations. I will conclude with an outlook on the future and how novel techniques have the potential to maximise the scientific return from upcoming experiments.

KEYWORDS cosmology, statistical methods, machine learning

General Field

#1169

Multisite and Multimessenger Projects and Campaigns as a Tool to Study of Stars, Star Clusters and Beyond

Alisher S. Hojaev[1]

[1]GA, UBAI, Uzbekistan

Despite the significant development of various modern methods for studying stars, especially from space observatories, the importance of their direct photometric study by obtaining time series remains relevant. In this sense, the high-altitude Maidanak observatory in Uzbekistan (Cental Asia) has sufficient experience, telescopes and equipment, including the newly acquired Andor state-of-the-art CCD cameras, developing infrastructure, exceptional location and seeing. One of the latest observational campaigns was a multi-messenger monitoring campaign for the cool flare star LP 245-10 = GJ 3147, successfully carried out in November 2021 in cooperation with the observatories of Taiwan, India and China. As part of the international grant program for the search for new and deep study of known variable stars, we also conduct long-term monitoring photometric observations of open star clusters, including young clusters and associations, as well as a number of specific variable stars (EB, MCV,N, SN, PMS and others) in collaboration with colleagues from ARIES (India). We will present the main features and benefits of Maidanak for future campaigns. We are open for any worldwide collaborations in multisite and multimessenger projects and campaigns and could discuss the possibilities as well as the operational strategies through my contact at hojaev@yahoo.com.

KEYWORDS multisite campaigns, multimessenger projects, stars, clusters, exoplanets, etc.

General Field

#1167

Multisite and Multimessenger Projects and Campaigns as a Tool to Study of Stars, Star Clusters and the Sun

Alisher S. Hojaev[1]

[1]GA, UBAI, Uzbekistan

Despite the significant development of various modern methods for studying stars, especially from space observatories, the importance of their direct photometric study by obtaining time series remains relevant. In this sense, the high-altitude Maidanak observatory in Uzbekistan (Cental Asia) has sufficient experience, telescopes and equipment, including the newly acquired Andor state-of-the-art CCD cameras, developing infrastructure, exceptional location and seeing. One of the latest observational campaigns was a multi-messenger monitoring campaign for the cool flare star LP 245-10 = GJ 3147, successfully carried out in November 2021 in cooperation with the observatories of Taiwan, India and China. As part of the international grant program for the search for new and deep study of known variable stars, we also conduct long-term monitoring photometric observations of open star clusters, including young clusters and associations, as well as a number of specific variable stars (EB, MCV,N, SN, PMS and others) in collaboration with colleagues from ARIES (India). We will present the main features and benefits of Maidanak for future campaigns. We are open for any worldwide collaborations in multisite and multimessenger projects and campaigns and could discuss the possibilities as well as the operational strategies through my contact at hojaev@yahoo.com.

KEYWORDS multimessenger projects, multisite observational campaigns, Sun, stars, star clusters

General Field

#823

Star formation beyond z=0 and its role in the multiverse

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The cosmological constant is accountable for the accelerated expansion of our Universe. Observational data have provided a tight constraint on the cosmic star formation history from $z = 8$ to the present. What happens to the star formation rate beyond $z=0$?

I will discuss the star formation rate, along with the properties of the intergalactic medium from our suite of simulations into the future. Since Lambda becomes dominant in the future of our universe, I further simulate counter-factual universes to assign anthropic weights to each universe within the multiverse setting.

I will argue that using the asymptotic star formation efficiency as weights, we almost double previous estimates of observers living in universes similar to ours. The expected value of the energy density of Lambda is also closer to the observed value. I will also discuss potential future works to improve the applicability of the anthropic reasoning of the cosmological constant.

KEYWORDS Cosmology, Galaxy evolution, Structure formation, Structure evolution

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