21st Cambridge Workshop: Cool Stars, Stellar Systems and the Sun

22 - 26 June 2020
Toulouse, France

Abstracts

Last updated: March 16, 2020

Contents

Connection to Internet

TBD (Eduroam etc.)

Foreword

From the chair SOC

Code of Conduct & Contact Information

Something similar to CS20?

Maps

Include local maps of Convention Centre etc.

Conference Schedule

<table>
<tr><th>Time</th><th>Sunday 21st</th><th>Monday 22nd</th><th>Tuesday 23rd</th><th>Wednesday 24th</th><th>Thursday 25th</th><th>Friday 26th</th></tr>
<tr><td>Topic</td><td></td><td>THE SUN IN TIME AND STELLAR EVOLUTION</td><td>MEASUREMENTS AT HIGH PRECISION</td><td>MAGNETISM OF THE SUN AND COOL STARS</td><td>THE ENVIRONMENTS OF THE SUN AND COOL STARS</td><td>COOL MEMBERS OF CLUSTERS AND ASSOCIATIONS</td></tr>
<tr><td>09:00-09:30</td><td></td><td>Invited Talk 1: A. Lanzafame</td><td>Invited Talk 3: J. Monnier</td><td>Invited Talk 5: J-F. Donati</td><td>Invited Talk 7: K. Korreck</td><td>Invited Talk 9: N. Bastian</td></tr>
<tr><td>09:30-09:45</td><td></td><td>Contributed Talk 1</td><td>CT9</td><td>CT17</td><td>CT25</td><td>CT33</td></tr>
<tr><td>09:45-10:00</td><td></td><td>CT2</td><td>CT10</td><td>CT18</td><td>CT26</td><td>CT34</td></tr>
<tr><td>10:00-10:15</td><td></td><td>CT3</td><td>CT11</td><td>CT19</td><td>CT27</td><td>CT35</td></tr>
<tr><td>10:15-10:30</td><td></td><td>CT4</td><td>CT12</td><td>CT20</td><td>CT28</td><td>CT36</td></tr>
<tr><td>10:30-11:15</td><td></td><td>Coffee break + Posters</td><td>Coffee break + Posters</td><td>Coffee break + Posters</td><td>Coffee break + Posters</td><td>Coffee break + Posters</td></tr>
<tr><td>11:15-11:45</td><td></td><td>Invited Talk 2: A. Palacios</td><td>Invited Talk 4: M. Cunha</td><td>Invited Talk 6: M. Kapyla</td><td>Invited Talk 8: A. Strugarek</td><td>Invited Talk 10: E. Zari</td></tr>
<tr><td>11:45-12:00</td><td></td><td>CT5</td><td>CT13</td><td>CT21</td><td>CT29</td><td>CT37</td></tr>
<tr><td>12:00-12:15</td><td></td><td>CT6</td><td>CT14</td><td>CT22</td><td>CT30</td><td>CT38</td></tr>
<tr><td>12:15-12:30</td><td></td><td>CT7</td><td>CT15</td><td>CT23</td><td>CT31</td><td>CT39</td></tr>
<tr><td>12:30-12:45</td><td></td><td>CT8</td><td>CT16</td><td>CT24</td><td>CT32</td><td>CT40</td></tr>
<tr><td>12:45-14:30</td><td></td><td>Lunch break</td><td>Lunch break</td><td>Lunch break</td><td>Lunch break</td><td>End of conference</td></tr>
<tr><td>14:30-16:00</td><td></td><td>Splinter sessions 1, 2, 3</td><td>Splinter sessions 4, 5, 6</td><td rowspan="4">Social Events</td><td>Splinter sessions 7, 8, 9</td><td rowspan="4">BBQ at Toulouse Observatory</td></tr>
<tr><td>16:00-16:30</td><td rowspan="3">Pre-registration</td><td>Coffee break + Posters</td><td>Coffee break + Posters</td><td>Coffee break + Posters</td></tr>
<tr><td>16:30-18:00</td><td>Splinter sessions 1, 2, 3</td><td>Splinter sessions 4, 5, 6</td><td>Splinter sessions 7, 8, 9</td></tr>
<tr><td>18:00-19:30</td><td>Posters</td><td>Invited Lecture: Nobel Prize Prof. M. Mayor</td><td>Posters</td></tr>
<tr><td>from 19:30</td><td></td><td>Ice Breaker</td><td></td><td></td><td>Banquet</td><td></td></tr>
</table>

Instructions for the Conference Proceedings

TBD (Zenodo etc.)

Talks

The Missing Members of Nearby Young Associations

Jonathan Gagné (1); Eric E. Mamajek (2); Jacqueline K. Faherty (3); Trevor J. David (4); Andrew W. Mann (5)

(1) Institute for Research on Exoplanets, Université de Montréal; (2) Jet Propulsion Laboratory, Caltech; (3) University of North Carolina at Chapel Hill; (4) American Museum of Natural History

I will present the latest developments in the search for members of young stellar associations in the Solar neighborhood, within 150 pc of the Sun. I will discuss the nature of these sparse and nearby associations and their utility as age-calibrating benchmarks. I will show how the recent Data Release 2 of the ESO Gaia mission is strongly impacting our understanding of the Solar neighborhood, including that of nearby young associations. I will talk about on-going projects to discover new associations entirely, and characterize the low-mass stars of these young associations based on Gaia, down to the brown dwarf mass regime. I will also touch on how near-infrared surveys like 2MASS and WISE allowed us to find a few members down in the regime of giant planet masses.

Spectroscopic Characterisation of 90 Southern Cool TESS Candidate Planet Hosts

Adam D. Rains; Maruša Žerjal; Michael J. Ireland; Michael S. Bessell; Thomas Nordlander; Luca Casagrande

Australian National University

Cool dwarfs young and old are the most numerous stars in the universe, and are critical to understand due to both this profusion but also to better study the lives of the planets they host. NASA's Transiting Exoplanet Survey Satellite, TESS, has now finished surveying the Southern Hemisphere and has returned a wealth of planet candidates orbiting such stars that are now actively being followed up by ground-based spectroscopic surveys. However, many of these stars are too faint to be effectively targeted by precision radial velocity surveys, leaving host star properties known only through photometry. Here we present the results of a spectroscopic survey of 90 cool (< 4500 K) southern TESS exoplanet candidates in the magnitude range 8.7 < G < 15.8. The stars were observed at medium resolution by the ANU 2.3 m Telescope over a wavelength range 3500-7000 A in late 2019 and early 2020. We derive stellar T_{eff}, log g, and [Fe/H] through both synthetic and data driven approaches, and compare the results to empirical relations. Many of our sample had no prior spectroscopic observations, so this work serves to expand our understanding of the coolest stars in Solar Neighbourhood with a uniform set of stellar parameters. Additionally, we compute precision stellar radii for our targets using bolometric fluxes and parallax measurements, enabling us to place radius constraints on the largest sample of TESS planets to date.

Magnetic field and activity is M giants - a long term study

Renada Konstantinova-Antova (1); Agnes Lèbre (2); Stefan Georgiev (3); Michel Aurière (4); Ana Palacios (5); Julien Morin (6); Eric Josselin (7); Natalia Drake (8); Rumen Bogdanovski (9); Svetla Tsvetkova (10); Ana Borisova (11); Philippe Mathias (12)

(1) Institute of Astronomy and NAO, Bulgarian Academy of Sciences; (2) LUPM, UMR 5299, Université de Montpellier, CNRS; (3) Institute of Astronomy and NAO, Bulgarian Academy of Sciences; (4) Université de Toulouse, IRAP; (5) LUPM, UMR 5299, Université de Montpellier, CNRS; (6) Laboratory of Observational Astrophysics, Saint Petersburg State University; (7) Institute of Astronomy and NAO, Bulgarian Academy of Sciences; (8) Université de Toulouse, IRAP.

A long-term (more than 10 years) spectropolarimetric and spectroscopic study of three magnetic M giants is presented. The Narval spectropolarimeter at the 2m TBL, Pic du Midi Observatory, France, is used for the whole study. The reasons for the long and short term variability of the magnetic field and activity is discussed in the context of the evolutionary stage and the relevant structure of these fairly evolved stars. The interplay between the magnetic field and pulsations is also explored.

The Evolution of Stellar Rotation

Jamie Tayar for the TESS Subgiant Team

Institute for Astronomy/University of Hawaii

Data from Kepler allowed us for the first time to understand the evolution of the internal rotation of evolved stars. These results told a complicated story, where main sequence stars were generally solid body rotators, whereas red giants showed large radial rotation gradients. I will present the first measurements of internal rotation using TESS data for subgiant and lower red giant stars and show that these results allow us to connect these two regimes. I will show that the ratio of the core and envelope rotation in this regime is a function of mass, which helps to explain the previous measurements of core rotation in red giants. I will also demonstrate that these new measurements are a challenge to explain in detail for current theories of internal angular momentum transport and discuss some possibilities for future progress.

Realistic Radiative MHD Modeling of Flare-productive Sunspots

Shin Toriumi (1); Hideyuki Hotta (2)

(1) Japan Aerospace Exploration Agency; (2) Chiba University

Observations revealed that the solar flares, especially the strongest events in history, emanate from complex-shaped sunspot regions. However, it has been extremely difficult to investigate the formation of sunspots because we cannot optically observe the subsurface layer of the Sun, where magnetic fields rise and build up sunspots on the photosphere. In this study, for the first time, we succeed in simulating the entire process, in which a subsurface magnetic flux tube is elevated by the turbulent background convection and spontaneously forms complex sunspots. We find that the sunspots have a "delta" configuration (the most eruptive category of sunspots) with a strong magnetic shear and helical flux rope structure, all off which are consistent with the observations of flare-prolific regions. In the presentation, we discuss the key roles of turbulent convection in producing such violent sunspots.

Differential rotation and meridional flows on the lower main sequence

Manfred Küker (1); Günther Rüdiger (2); Klaus Strassmeier (3); Katalin Oláh (4)

(1) Leibniz-Institut für Astrophysik Potsdam; (2) Konkoly Observatory Budapest

Mean field models reproduce the observed differential rotation pattern and surface meridional flow of the Sun. Predictions for other stars on the lower main sequence are consistent with observations but raise questions about the validity of the flux transport dynamo as the mechanism behind stellar activity. This is particularly true for early M dwarfs, which show cycle times much shorter than the turnover times predicted by mean field models.

The solar wind angular momentum: what's new with Parker Solar Probe?

Victor Réville (1); Marco Velli (2); Alexis Rouillard (3); Benoit Lavraud (4)

(1) CNRS/IRAP; (2) UCLA; (3) CNRS/IRAP; (4) CNRS/IRAP

The first few orbits of the Parker Solar Probe have already shaken up our most advanced theories on the solar wind acceleration and angular momentum transport. Non-linear, large amplitude Alfvén waves, called switchbacks, have been observed constantly and may be a fundamental, unexpected, ingredient of the solar wind driving. A surprisingly high co-rotation of the solar wind particles has also been measured at the closest approach of the PSP. This latter observation shatters our hopes to settle the question of the measurement of the solar wind angular momentum once and for all and suggests that something fundamental to the solar and stellar wind braking has yet to be understood. In this talk, I will detail some of the possible explanations for these high azimuthal velocity measurements, such as compression and co-rotating interaction regions, temperature anisotropies and switchback dynamics. I will rely on newly developed simulations of the solar corona and wind as well as simplified analytical calculations. Finally, I will draw some of the potential consequences of these observations on the modeling of cool stars' rotation evolution on secular timescales.

Can sub-photospheric magnetic reconnection change the elemental composition in the corona?

Deborah Baker (1); Lidia van Driel-Gesztelyi (2); David H. Brooks (3); Pascal Démoulin (4); Gherardo Valori (5); David M. Long (6); J. Martin Laming (7); Andy S. H. To (8); Alexander W. James (9); Katalin Oláh (10); Zsolt Kővári (11); Lucie M. Green (12); Sarah A. Matthews (13)

(1) University College London, Mullard Space Science Laboratory; (2) University College London, Mullard Space Science Laboratory, LESIA, Observatoire de Paris, Université PSL, CNRS, Sorbonne Université, Univ. Paris Diderot, Sorbonne Paris Cité, Konkoly Observatory, Research Centre for Astronomy and Earth Sciences; (3) College of Science, George Mason University; (4) LESIA, Observatoire de Paris, Université PSL, CNRS, Sorbonne Université, Univ. Paris Diderot, Sorbonne Paris Cité; (5) University College London, Mullard Space Science Laboratory; (6) University College London, Mullard Space Science Laboratory; (7) Space Science Division, Naval Research Laboratory; (8) European Space Astronomy Centre; (9) Konkoly Observatory; (10) Konkoly Observatory; (11) University College London, Mullard Space Science Laboratory; (12) University College London, Mullard Space Science Laboratory

Within the coronae of stars, abundances of those elements with low first ionization potential (FIP) often differ from their photospheric values. The coronae of the Sun and solar-type stars mostly show enhancements of low-FIP elements (the FIP effect) where more active stars such as M-dwarfs have coronae generally characterized by the inverse-FIP effect (I-FIP). Using Hinode/EIS we observe patches of I-FIP effect solar plasma in the midst of FIP-effect plasma in two magnetically complex active regions while magnetic flux is emerging. We argue that the umbrae of coalescing sunspots and more specifically strong light bridges, are preferential locations for observing I-FIP effect plasma. Furthermore, the magnetic complexity of the active region and major episodes of fast flux emergence also lead to repetitive and intense flares. The induced evaporation of the chromospheric plasma in flare ribbons crossing the coalescing umbrae produces high enugh temperatures to enable the observation of localized patches of I-FIP effect plasma in the corona. These observations can be interpreted in the context of the ponderomotive force fractionation model, which predicts that plasma with I-FIP effect composition is created by the refraction of waves coming from below the chromosphere. The refraction takes place in the chromosphere due to a high density gradient there. We propose that the waves generating the I-FIP effect plasma in solar active regions are generated by sub-photospheric (component) reconnection of coalescing flux systems. Although we only glimpse signatures of I-FIP effect fractionation produced by this interaction in patches on the Sun, on highly active M-stars it may be the dominant process.

Unraveling the nature of ultra-fast rotators with ASTROSAT

Lalitha Sairam (1); K.P. Singh (2); J.H.M.M. Schmitt (3)

(1) University of Birmingham; (2) Indian Institute of Science Education and Research Mohali, India; (3) Hamburger Sternwarte, University of Hamburg

The Sun is often considered to be a prototype of ultra-fast rotating stars. We often extrapolate the knowledge inferred from the Sun to these stars. However, several studies have shown that the spatial correlation between the different layers of the atmosphere and their associated activity phenomena may or may not be similar to the Sun. Although stellar magnetic activity has been investigated for decades, the exact mechanism controlling the activity of fast-rotating stars are still not understood. We systematically characterise the stellar activity of fast-rotators in the optical, X-ray and UV regime with AstroSat, a multi-wavelength observatory. In this talk, I will invoke how such a multi-wavelength study allows us to localise activity features on the stellar surface and the heating mechanism of the outer layers of the stellar atmosphere.

Surface magnetic field effect on stellar limb darkening.

N. M. Kostogryz (1); V. Witzke (2); A. I. Shapiro (3); P. F. L. Maxted (4); L. Gizon, S. K. Solanki (5)

(1) Max Planck Institute for Solar System Research; (2) Max Planck Institute for Solar System Research; (3) Max Planck Institute for Solar System Research; (4) Astrophysics Group at Keele University; (5) Max Planck Institute for Solar System Research/Institut für Astrophysik, Georg-August-Universität Göttingen; (6) Max Planck Institute for Solar System Research/School of Space Research at Kyung Hee University

Limb darkening of stellar atmospheres defines the shape of the transit light curve and also affects its depth. Therefore knowledge of the limb darkening is crucial for retrieving parameters of exoplanets from transit light curves. We employ the newly developed 1-D MPS-ATLAS code to create a grid of model atmospheres and the corresponding limb darkening for a wide range of stellar fundamental parameters. Moreover, we perform 3-D hydrodynamical (HD) and magnetohydrodynamical (MHD) simulations using the MURaM code for selected combinations of fundamental parameters. We show that our 1-D calculations lead to the limb darkening very similar to those returned by the 3D HD MURaM simulations. At the same time a comparison of HD and MHD 3-D simulations shows that surface magnetic field has a strong effect on the limb darkening functions, and leads to a better agreement with observations.

The Sun is less active than other solar-like stars

Timo Reinhold (1); Alexander I. Shapiro (2); Sami K. Solanki (3); Benjamin T. Montet (4); Natalie A. Krivova (5); Robert H. Cameron (6); Eliana M. Amazo-Gomez (7)

(1) Max Planck Institute for Solar System Research (MPS); (2) MPS; (3) MPS & School of Space Research, Kyung Hee University, Yongin, Gyeonggi, 446-701, Korea; (4) School of Physics, University of New South Wales, Sydney, NSW 2052, Australia; (5) MPS; (6) MPS; (7) MPS & Georg-August University, Institute for Astrophysics, 37077 Goettingen, Germany

Over the past decades it has been discussed whether the Sun is less active than other stars with near-solar effective temperatures and rotation periods. Since stellar magnetic activity and photometric variability are strongly correlated, we compare the Sun's activity to other solar-like stars. By combining four years of photometric observations from the Kepler space telescope with astrometric data from the Gaia spacecraft, we measure photometric variabilities of hundreds of solar-like stars. Most of the solar-like stars with well-determined rotation periods show higher variability than the Sun and are therefore considerably more active. These stars appear nearly identical to the Sun, except for the higher variability. Their existence raises the question of whether the Sun can also experience epochs of such high variability.

Magnetic field and accretion in the young eruptive star EX Lupi

Péter Ábrahám (1); Ágnes Kóspál (2); Andrés Carmona (3); Jean-François Donati (4); Jerôme Bouvier (5); Kundan Kadam (6); Aurora Sicilia-Aguilar (7); Collin Folson (8)

(1) Konkoly Observatory Budapest; (2) Konkoly Observatory Budapest, MPIA Heidelberg; (3) IPAG Grenoble; (4) IRAP Toulouse; (5) IPAG Grenoble; (6) Konkoly Observatory Budapest; (7) University of Dundee; (8) IRAP Toulouse

EX Lup is the younger sibling of our Sun. It is a low-mass star with an age of a few million years, which still possesses a strong magnetic field and accretes material actively from its circumstellar disk. According to numerical simulations, the magnetic interaction of the star and its disk may lead to bursts of increased accretion onto the star. An observable example of this phenomenon is EX Lup, which show irregular brightenings due to elevated accretion, giving name to a group of young stars called EXors. EX Lup had its historically largest outburst in 2008. Spectra from its quiescent and outburst periods indicate that the mass accretion proceeds through the same magnetospheric accretion channels in both periods but with different mass flux. Here, we present a study of the magnetic field structure and accretion process in EX Lup. We monitored the star in 2016 June with the CFHT/ESPaDOnS spectropolarimeter and detected strong and largely poloidal topology with a prominent cool polar cap and an accretion spot above it. Our multi-filter optical/near-infrared photometric monitoring between 2016 and 2019 with the SMARTS 1.3m telescope suggests that the location and extent of the spot varied over the years. We also present recent results from our coordinated CFHT/ESPaDOnS and CFHT/SPIRou spectropolarimetric monitoring of EX Lup at the same time as the TESS satellite measured it. If EX Lup is a good proxy for the proto-Sun, similar

magnetic field-disk interactions and the resulting outbursts might have happened during the early evolution of the Solar System as well, shaping the formation of the terrestrial planets.

The accretion process in the DQ Tau pre-main sequence binary system

Ágnes Kóspál (1); Evelyne Alecian (2); Péter Ábrahám (3); Jerôme Bouvier (4); Jean-François Donati (5); Andrés Carmona (6); Benjámin Vígh (7)

(1) Konkoly Observatory Budapest, MPIA Heidelberg; (2) IPAG Grenoble; (3) Konkoly Observatory Budapest; (4) IPAG Grenoble; (5) IRAP Toulouse; (6) IPAG Grenoble; (7) Konkoly Observatory Budapest

DQ Tau is a pre-main sequence spectroscopic binary consisting of two M1-type stars on an eccentric orbit surrounded by a circumbinary disk. It's the prototype system for pulsed accretion, a phenomenon during which the binary periodically accretes material from the disk synchronized with the binary's orbital period. DQ Tau is also among the few young stars exhibiting strong, recurrent millimeter flares explained by interaction between the stars' magnetospheres during periastron. Kepler/K2 light curves revealed a rotational modulation by stellar spots with a rotational period of 3.017+/-0.004 days, brief brightening events due to stellar flares, long brightening events around periastron due to increased accretion, and short dips due to brief circumstellar obscuration. Here, we present new VLT/XSHOOTER and CFHT/ESPaDOnS monitoring of DQ Tau. We analyze 8 XSHOOTER spectra taken between 2012 November and 2013 March covering the 300 - 2470 nm wavelength range, and 3 ESPaDOnS spectra taken in 2019 November, covering the 370 - 1050 nm wavelength range. We detect significant variability of the emission line strengths and profiles, as well as of the veiling of the absorption lines over the orbital period of the binary, confirming variable accretion. We discovered forbidden emission lines, indicating the presence of shocked material in the system. Our spectropolarimetric data display clear Zeeman-signature, but the magnetic field in the system is relatively weak. With this project, we aim to further our knowledge on how mass accretion happens in a binary, an important question because many low-mass Sun-like stars are born in multiple systems.

What have we learned about Milky Way's young substellar population?

Koraljka Muzic (1); Aleks Scholz (2); Victor Almendros-Abad (3); Karolina Kubiak (4)

(1) CENTRA University of Lisbon; (2) St Andrews University; (3) CENTRA University of Lisbon; (4) CENTRA University of Lisbon

Young clusters and star forming regions are home to a large number of substellar objects with masses below the hydrogen-burning limit at $\sim$0.075 $M_\odot$. Most of our knowledge about their populations is coming from nearby regions (d$<$400 pc), where we find consistent formation rates of 2-5 young brown dwarfs per 10 newborn stars. Brown dwarf theories, on the other hand, predict that high gas or stellar densities, as well as the presence of massive OB stars, may be factors that boost the incidence of newly formed brown dwarfs with respect to stars. The next frontier in substellar studies, therefore, is their identification in massive clusters, characterized by drastically different star-forming environments than those found in our immediate vicinity. In this contribution I will compare the outcome of our decade-long deep survey SONYC (Substellar Objects in Nearby Young Clusters), with the results of our new project in massive young clusters, in which we confirm the first

bona fide brown dwarfs beyond 1 kpc. I will also discuss the trials and tribulations of membership confirmation in this mass and age regime.

Effect of metallicity on small-scale magnetic flux in Sun-like stars

A. I. Shapiro; D. Przybylski; R. H. Cameron; S. K. Solanki; N. A. Krivova

Max Planck Institute for Solar System Research, School of Space Research, Kyung Hee University

Stellar activity is driven by magnetic fields emerging from below the stellar surface and evolving due to the complex interaction of gas dynamics and magnetic flux. The concentrations of magnetic fields on stellar surfaces form various magnetic features, e.g. faculae. Moreover, even when stellar activity is completely absent above a basal level, there is a minimum level of magnetic flux. This so-called basal flux is due to a local small-scale dynamo (SSD) near the surface.

Previous investigations of near-surface magneto-convection simulations have demonstrated an important effect of the stellar effective temperature on the underlying physics of stellar magnetic features, finding significant influences on the bolometric intensity, velocity patterns and lifetime of surface magnetic fields. Another fundamental stellar parameter is metallicity, the effect of which was mostly ignored in realistic 3D MHD calculations until now. In particular, while extensive studies for several metallicities exist for pure hydrodynamic~(HD) 3D models, we lack understanding how metallicity will affect magnetic structures.

Here, we focus on the effect of metallicity on stellar near-surface dynamics in the presence of magnetic fields. Using radiative 3D MHD calculations by the `MURaM` code we simulate Sun-like stars with metallicity values ranging from $\mathrm{M/H} = -1.0$ to $\mathrm{M/H} = 0.5$. To describe the quiet stellar surface, we consider both purely hydrodynamic and SSD runs. To obtain different levels of magnetic activity we use runs with initial vertical magnetic fields of different strengths. Our study not only investigates the fundamental properties of near-surface dynamics in solar-like stars of different metallicity, but also forms the base for numerous applications, such as modelling stellar brightness variability, and determining centre-to-limb variations.

Spitzer Mid-IR Monitoring of Young Giant Planet Analogs

Jacqueline Faherty (1); Kelle Cruz (2); Emily Rice (3); Jonathan Gagné (4); Mark Marley (5); John Gizis (6)

(1) American Museum of Natural History; (2) American Museum of Natural History; (3) CUNY, Hunter College; (4) CUNY, Macaulay Honors College; (5) University of Montreal; (6) NASA Ames; (7) University of Delaware

Photometric variability monitoring is sensitive to atmospheric features as they rotate in and out of view, allowing us to probe the presence of surface inhomogeneities caused by patchy clouds, hot spots and temperature fluctuations. Periodic variability has been detected in brown dwarfs with temperatures spanning 250 - 2200 K, and recently in a sample of free-floating, planetary-mass objects. These young, isolated, low-gravity objects share a striking resemblance with the directly-imaged planets and can be studied in far greater detail in the absence of a bright host star. The large amplitudes observed in this small sample of low-gravity objects suggests that variability may be enhanced for the exoplanet analogues. I will present results from a large Spitzer survey searching for variability in young, giant planet analogs, and discuss how these results reveal how the temperature, surface-gravity, rotation rate and inclination can influence observed variability properties.

Global Solar Magnetic Variations using Spectroscopic Proxies and Excess Brightness Indices

Ekaterina Dineva (1); Jeniveve Pearson (2); Meetu Verma (3); Carsten Denker (4); Klaus G. Strassmeier (5); Ilya Ilyin (6)

(1) Leibniz Institute for Astrophysics Potsdam (AIP)/ University of Potsdam; (2) Ohio State University; (3) Leibniz Institute for Astrophysics Potsdam (AIP); (4) Leibniz Institute for Astrophysics Potsdam (AIP); (5) Leibniz Institute for Astrophysics Potsdam (AIP)/ University of Potsdam; (6) Leibniz Institute for Astrophysics Potsdam (AIP)

The Potsdam Echelle Polarimetric and Spectroscopic Instrument (PEPSI) is a state-of-the-art, thermally stabilized, fiber-fed, high-resolution spectrograph for the Large Binocular Telescope (LBT) at Mt. Graham, Arizona. It can be fed with sunlight from the Solar Disk-Integrated (SDI) telescope. Synoptic solar observations with PEPSI/SDI produce daily spectra with high signal-to-noise ratio, providing access to unprecedented, quasi-continuous, long-term, disk-integrated spectra of the Sun with high spectral and temporal resolution. The observed spectra contain a multitude of photospheric and chromospheric spectral lines in the wavelength range of 380 – 910$\sim$nm. Strong chromospheric absorption lines, such as the Ca II H & K lines, are powerful diagnostic tools for solar activity studies, since they trace the variations of the solar magnetic field. Derivation of activity indices, such as the Ca II H & K emission ratio S-index provides insight into the chromospheric magnetic field and its variability over the solar activity cycle. The well known relation between solar calcium indices and UV flux variations motivates us to compute an excess brightness indices from Ca II K full-disk images from of the Chromospheric Telescope (ChroTel) at the Observatory del Teide on Tenerife, Spain and UV data of the Solar Dynamics Observatory (SDO). We present a set of indices representing magnetic activity at various heights in the solar atmosphere. In the present work, we carefully compare the indices computed from various datasets and discuss the differences in terms of physical and observational properties.

Disks and outflows of FUor-type stars observed with ALMA

Ágnes Kóspal (1); Péter Ábrahám (2); Michihiro Takami (3)

(1) Konkoly Observatory & Max Planck Institute for Astronomy; (2) Konkoly Observatory; (3) Institute of Astronomy and Astrophysics, Academia Sinica

FU Orionis-type stars (FUors) are low-mass young stellar objects experiencing brief periods of an enhanced mass accretion rate. The episodic nature of the accretion outbursts has been proposed as a solution for the “luminosity problem” where protostars are less luminous that theoretically expected. Previous observations of these objects have shown the compact nature of their protoplanetary disks and, in some cases, massive outflows emanating from them have been observed with different gas tracers. In this work we present the results of our ALMA survey in which we observed 10 different FUor-like objects using the 1.33 mm continuum and the J=2–1 transitions of ^{12}CO, ^{13}CO and C^{18}O. Our observations consist of two ALMA extended configurations supported by ACA and single dish data. This setup provides us with high angular resolution ($\sim$18 mas) while preserving the short spacing information. As part of our results in the continuum, we analyzed the observed visibilities to determine the disk sizes and masses. In the CO, we recovered outflow emission from several of our targets, and found indications of Keplerian rotation and infalling material. We will also present our serendipitous detection of complex organic molecules and sulfur based molecules. Finally, we will put our sample into context by comparing it to quiescent and other outbursting protostars.

Magnetic Variability of Ultracool Dwarfs from TESS

Sarah J. Schmidt (1); Ekaterina Ilin (2); J. Sebastian Pineda (3); Elisabeth R. Newton (4); James R. A. Davenport (5); Adam J. Burgasser (6)

(1) Leibniz Institute for Astrophysics - Potsdam (AIP); (2) Leibniz Institute for Astrophysics - Potsdam (AIP); (3) University of Colorado; (4) Dartmouth College; (5) University of Washington; (6) University of California San Diego

Ultracool dwarfs (spectral types M6-L3) encompass both the lowest mass stars and warmest brown dwarfs. Fast rotation periods and strong magnetic fields persist to older ages than for main sequence stars so that most ultracool dwarfs are intrinsically variable. Their magnetic activity gives rise to surface spots and dramatic flares. This activity has been traced by a number of different indicators such as radio, x-ray, and Hα emission. The presence and frequency of flares provides a magnetic tracer that is sensitive to changes in spectral type, rotation, and age in most partly und fully convective stars. Data from time domain surveys provides the unique opportunity to study both rotation periods and flares for increasingly large samples of stars. We initiated a program to examine ultracool dwarf rotational and flaring variability using NASA's Transiting Exoplanet Survey Satellite (TESS) two-minute cadence data. We present initial stellar properties, rotation periods, and flare frequency distributions for over one hundred ultracool dwarfs observed with TESS. In our initial results, we find that ultracool dwarfs flare more frequently than expected based on previous studies, but the flare rate does not depend strongly on spectral type.

Open Cluster Surveys Reveal a Temporary Epoch of Stalled Spin-Down

Jason Lee Curtis

American Museum of Natural History

Recent measurements of stellar rotation periods in benchmark open clusters demonstrate that, after converging onto a tight sequence of slowly rotating stars in mass-period space, stars temporarily stop spinning down. These data also show that the duration of this epoch of stalled spin-down increases toward lower masses. To determine when stalled stars resume spinning down, we used ground- and space-based time series imaging data (e.g., Kepler, K2, TESS, PTF, ZTF) to measure rotation periods for low-mass members of four old open clusters: NGC 6811 (1.0 Gyr), NGC 752 (1.4 Gyr), Ruprecht 147 (2.7 Gyr), and M67 (4 Gyr). The sequence of slowly rotating stars for Ruprecht 147 appears relatively flat, in sharp contrast with the steep mass dependence seen in the younger clusters, where periods tend to get longer toward decreasing mass. We suggest that this flat sequence is produced by the mass-dependent duration of the epoch of stalled braking: while the higher-mass stars spin more rapidly than lower-mass stars at the age of Praesepe (700 Myr), they resume spinning down earlier, and so catch up to their lower-mass siblings just as these resume spinning down. We calculate the time at which stars resume spinning down, and find that 0.55 $M_{\odot}$ stars remain stalled for at least 1.3 Gyr. The steep mass dependence also means that this phenomenon might present a big obstacle for age-dating stars of even lower mass with rotation. To accurately age-date low-mass stars in the field, gyrochronology formulae must be modified to account for this stalling timescale. Empirically tuning a core-envelope coupling model with open cluster data can account for most of the apparent stalling effect. However, alternative explanations, e.g., a temporary reduction in the magnetic braking torque, cannot yet be ruled out.

Tracking density variations in the Solar corona

Léa Griton (1); Alexis P. Rouillard (2); Rui Pinto (3); Athanasios Kouloumvakos (4); Nicolas Poirier (5); Michaël Lavarra (6); Victor Réville (7); Benoît Lavraud (8); Marco Velli (9); Nour-Eddine Raouafi (10)

(1) IRAP, Université de Toulouse, CNRS, CNES, UPS, (Toulouse), France ; (2) IRAP, Université de Toulouse, CNRS, CNES, UPS, (Toulouse), France ; (3) IRAP, Université de Toulouse, CNRS, CNES, UPS, (Toulouse), France ; (4) IRAP, Université de Toulouse, CNRS, CNES, UPS, (Toulouse), France ; (5) IRAP, Université de Toulouse, CNRS, CNES, UPS, (Toulouse), France ; (6) IRAP, Université de Toulouse, CNRS, CNES, UPS, (Toulouse), France; (7) IRAP, Université de Toulouse, CNRS, CNES, UPS, (Toulouse), France ; (8) IRAP, Université de Toulouse, CNRS, CNES, UPS, (Toulouse), France ; (9) Institute of Geophysics & Planetary Physics, Department of Earth, Planetary & Space Sciences, University of California, Los Angeles, CA, USA) ; (10) Johns Hopkins University, Applied Physics Laboratory, Laurel, MD, USA

The recent analysis of Parker Solar Probe's (PSP's) second encounter compared with data taken by the Solar and Heliospheric Observatory (SOHO) and Solar TErrestrial RElations Observatory (STEREO) A (STA) revealed for the first time a close link between the high-density plasma measured by PSP and streamer flows imaged by instruments at 1$\sim$AU from the Sun. We exploit observations when STA was in orbital quadrature with PSP to track the release and propagation of dense material from the corona to PSP. The analysis of time-elongation maps, built from STA images, show that PSP was impacted continually by the southern edge of streamer transients inducing clear density increases measured in situ by the plasma instrument. Considering PSP's first and second encounters, we also find evidence that the impact of specific dense structures is correlated with a higher occurrence of magnetic field reversals. These magnetic reversals are associated with strong density variations when associated with streamer flows, but with weak density variations outside streamer flows. We present a detailed analysis of the properties of switchbacks in these different slow flows. We compare the magnetic and speed components as well as the correlation between speed and density. This work was funded by the European Research Council through the project SLOW_SOURCE - DLV-819189.

Modelling the link between UV emission and stellar magnetic activity

Sowmya Krishnamurthy(1) (1); Alexander I. Shapiro(1) (2); Veronika Witzke(1) (3); Nina-Elisabeth Nemec(1) (4); Theodosios Chatzistergos(2) (5); Natalie A. Krivova(1) (6); Sami K. Solanki(1,3) (7)

(1) (1)Max-Planck-Institut für Sonnensystemforschung, Justus-von-Liebig-Weg 3, 37077 Göttingen, Germany; (2) (2)INAF Osservatorio Astronomico di Roma, Via Frascati 33, 00078 Monte Porzio Catone, Italy; (3) (3)School of Space Research, Kyung Hee University, YongIn, Gyeonggi 446–701, Korea

The emission in the near ultraviolet Ca ii H & K lines is modulated by the magnetic activity of a star. Although this emission has been serving as a prime proxy of magnetic activity for several decades, many aspects of the complex relation between stellar magnetism and Ca ii H & K emission are still unclear. In particular, it was suspected that Ca ii H & K emission might be also affected by the inclination of a star's rotation axis and stellar metallicity but until now these effects have remained largely unexplored. In order to fill in this gap we develop a physics-based model of Ca ii H & K emission which enables us to study such dependencies. We first test this model for the case of the Sun, making use of the distributions of the solar magnetic features derived from observations together with the Ca ii spectra synthesized with a non-LTE radiative transfer code. Its performance is

validated by successfully reconstructing the observed variations of Ca ii emission across four solar activity cycles. We then use our model to obtain a time-series of the Ca ii emission over a period of 300 years in the past. With the help of this time-series we investigate the effects of stellar inclination and metallicity. In particular, we find that for solar-like distribution of magnetic features, during the cycle maximum, the Ca ii emission increases gradually as the angle between the direction to the observer and stellar rotation axis increases, while we see an opposite trend for the cycle minimum. Our work allows us to better understand the intricate coupling between the stellar parameters and Ca ii emission, thus enhancing the diagnostic potential of these emission measurements.

Investigating the Atmospheric Compositions of Ultra-Cool Brown Dwarfs Using High Resolution Spectroscopy

Nicole Wallack (1); Heather Knutson (2); Marta Bryan (3); Caroline Morley (4); Geoffrey Blake (5); Brendan Bowler (6); Courtney Dressing (7); Emily Martin (8); Andrew Skemer (9)

(1) Caltech; (2) Caltech; (3) UC Berkeley; (4) The University of Texas at Austin; (5) Caltech; (6) The University of Texas at Austin; (7) UC Berkeley; (8) UC Santa Cruz; (9) UC Santa Cruz

Ultra-cool brown dwarfs serve as an important link between gas giant exoplanets and stars. These objects are expected to have atmospheric chemistries similar to those of cool (<1000 K) transiting gas giant planets, and therefore serve as an important testing ground for atmosphere models. Although we can detect thermal emission from cool transiting gas giant exoplanets by observing secondary eclipses with the Spitzer Space Telescope, we must rely on forward models to interpret these relatively low SNR photometric data. Isolated or wide separation ultra-cool brown dwarfs, on the other hand, can be observed at both higher resolution and higher SNR using ground based facilities such as the recently upgraded NIRSPEC instrument on Keck. These observations provide an invaluable opportunity to evaluate the accuracy of the models used to interpret exoplanet spectra in this temperature regime. In this study we obtain high-resolution (R$\sim$25,000) K band spectra for two ultra-cool brown dwarfs with temperatures of 500 and 700 K, and detect absorption from methane, ammonia, and water. We combine these data with previously published low and medium resolution observations of these objects in order to derive updated constraints on their effective temperatures, surface gravities, and metallicities using a machine learning retrieval method leveraging the recently published Sonora model grid (Fisher et al. 2019, Marley et al. in prep). We also use these same data to explore possible modifications to the models that have the potential to improve the overall quality of the fit.

Activity-related Oscillation Mode Frequency Shifts from the Main Sequence to the AGB - Theory, Measurement, Implications

René Kiefer; Anne-Marie Broomhall

University of Warwick, Centre for Fusion, Space and Astrophysics, Coventry, UK

The properties of stellar oscillation eigenmodes change with the level of magnetic activity. This has been measured with data from CoRoT and *Kepler*, where signatures of magnetic activity have been found in the seismic properties of a few dozen main-sequence and sub-giant stars. However, as of yet, no detection of temporal variations in the oscillation frequencies of more evolved stars have been reported.

Theory: To gauge the sensitivity of p modes to magnetic perturbations through stellar evolution, we calculate the mode sensitivity factors of radial p modes for a set of MESA models with initial

masses between 0.7–3.0 $M_\odot$ from the main sequence to the early asymptotic giant branch. The mode eigenfunctions are calculated with GYRE. We fit these mode sensitivities with polynomials in fundamental stellar parameters and find that the best-fitting relations differ from those proposed in the literature and that they change between stages of stellar evolution.

Measurements: We analyse the *Kepler* long cadence data for the red giant sample compiled by Yu et al. (2018, ApJS 236:42) which consists of ~16,000 stars. To expand the sample, we added 415 main-sequence and subgiant stars investigated by Serenelli et al. (APOKASC, 2017, ApJS 233:23) and the previously published frequency shifts for a sample of 87 main-sequence and subgiant stars of Santos et al. (2018, ApJS 237:17). To obtain the frequency shifts, we use a cross-correlation technique which is well suited for such a large sample of stars, as the only required input parameters are frequency of maximum oscillation amplitude ν_{max} and the large frequency separation $\Delta\nu$.

We find significant frequency shifts for about 2500 stars of the red giant sample and for 90 stars of the APOKASC sample. Interestingly, stars in the core helium burning phase (as identified by Yu et al.) show larger shifts than stars on the red giant branch. **Implications**: Together with a measure of the strength of the level of magnetic activity, the polynomial scaling relations for the mode sensitivities can be used for assessing whether a star's observed oscillation frequencies are likely to be close to the unperturbed ground state or whether they should be adjusted. This can be important if individual mode frequencies are used for stellar modelling or if ν_{max} and $\Delta\nu$ are used to estimate stellar masses and radii. We compare the detected frequency shifts with predictions from our theoretical scaling relations. Further, we discuss implications of the found levels of frequency perturbations and possible means to obtain the "ground state" frequencies.

Surface magnetic field effect on stellar limb darkening.

N. M. Kostogryz (1); V. Witzke (2); A. I. Shapiro (3); P. F. L. Maxted (4); L. Gizon, S. K. Solanki (5)

(1) Max Planck Institute for Solar System Research; (2) Max Planck Institute for Solar System Research; (3) Max Planck Institute for Solar System Research; (4) Astrophysics Group at Keele University; (5) Max Planck Institute for Solar System Research/Institut für Astrophysik, Georg-August-Universität Göttingen; (6) Max Planck Institute for Solar System Research/School of Space Research at Kyung Hee University

Limb darkening of stellar atmospheres defines the shape of the transit light curve and also affects its depth. Therefore knowledge of the limb darkening is crucial for retrieving parameters of exoplanets from transit light curves. We employ the newly developed 1-D MPS-ATLAS code to create a grid of model atmospheres and the corresponding limb darkening for a wide range of stellar fundamental parameters. Moreover, we perform 3-D hydrodynamical (HD) and magnetohydrodynamical (MHD) simulations using the MURaM code for selected combinations of fundamental parameters. We show that our 1-D calculations lead to the limb darkening very similar to those returned by the 3D HD MURaM simulations. At the same time a comparison of HD and MHD 3-D simulations shows that surface magnetic field has a strong effect on the limb darkening functions, and leads to a better agreement with observations.

Probing fossil magnetism effects in the core of evolved low-mass stars using mixed-mode frequencies

Lisa Bugnet (1); Vincent Prat (2); Stéphane Mathis (3); Rafael A. García (4); Savita Mathur (5); Kyle Augustson (6); Coralie Neiner (7)

(1) AIM, CEA, CNRS, Université Paris-Saclay, Université Paris Diderot, Sorbonne Paris Cité, F-91191 Gif-sur-Yvette, France; (2) AIM, CEA, CNRS, Université Paris-Saclay, Université Paris Diderot, Sorbonne Paris Cité, F-91191 Gif-sur-Yvette, France; (3) AIM, CEA, CNRS, Université Paris-Saclay, Université Paris Diderot, Sorbonne Paris Cité, F-91191 Gif-sur-Yvette, France; (4) AIM, CEA, CNRS, Université Paris-Saclay, Université Paris Diderot, Sorbonne Paris Cité, F-91191 Gif-sur-Yvette, France; (5) Instituto de Astrofisica de Canarias, E-38200, La Laguna, Tenerife, Spain; (6) AIM, CEA, CNRS, Université Paris-Saclay, Université Paris Diderot, Sorbonne Paris Cité, F-91191 Gif-sur-Yvette, France; (7) LESIA, Paris Observatory, CNRS, PSL University, Sorbonne Université, Univ. Paris Diderot, Sorbonne Paris Cité, 5 place Jules Janssen, 92195 Meudon, France

From the flat rotation profile of the inner Sun to the interestingly low rotation rate of the core of red giants, which is about 10 times lower than what is predicted by the current theory of dynamical processes, the stellar angular momentum transport is poorly understood inside low-mass solar-like stars all along their evolution. The recent discovery of red giants more massive than $\sim 1.3\ M_{\odot}$ that present a surprisingly low amplitude of the mixed (i.e. modes that behave as acoustic modes in the external envelope and as gravity modes in the core of evolved stars) dipolar and quadrupolar modes could be the signature of a strong magnetic field trapped inside the radiative interior of intermediate mass stars. Regarding the presence of highly magnetised white dwarfs, we seek a missing process taking place inside the core of evolved low-mass stars to efficiently transport angular momentum from the core to the surface. Such a process could arise from strong internal magnetism. In this context, the mixed modes observed thanks to CoRoT, Kepler/K2 and TESS space missions can constitute an excellent probe of the deepest layers in evolved stars. Stars more massive than ~ 1.3 $M_{\odot}$ are known to develop a convective core during the main-sequence: the dynamo process due to this convection could be the origin of a strong magnetic field, trapped inside the core of the star for the rest of its evolution. Such magnetic fields should impact the mixed modes inside the core of RG stars, and their signature should be visible in asteroseismic data. To unravel which constraints can be obtained from these asteroseismic observations, we theoretically investigate the effects of a plausible mixed magnetic field with various amplitudes on the mixed-mode frequencies for subgiant and red giant stars. Applying a perturbative method along with an order-of-magnitude analysis, we estimate the magnetic perturbation on the frequencies of mixed dipolar modes, depending on the magnetic field strength and its configuration. It is then possible to infer an upper limit for the strength of the field and the associated lower limit for the timescales of its action to redistribute angular momentum in stellar interiors.

Complex Structure of a Proto-Brown Dwarf

B. Riaz (1); M. N. Machida (2)

(1) Universitats-Sternwarte Munchen, Ludwig-Maximilians-Universitat, Scheinerstr. 1, 81679 Munchen, Germany; (2) Department of Earth and Planetary Sciences, Faculty of Sciences, Kyushu University, Fukuoka, Japan

We present ALMA 12CO (2-1), 13CO (2-1), C18O (2-1) molecular line observations of a very young proto-brown dwarf (proto-BD) system in its early formation stages. We have conducted physical-chemical modelling of the complex internal structure for this proto-BD system using the physical structure from the core collapse simulations for brown dwarf formation at different evolutionary stages. We have shown that the model at a stage of ~6000 yr can provide a good fit to the 12CO (2-1), 13CO (2-1), and C18O spectra and reproduce the complex structures seen in the observed integrated intensity maps. Results from modelling the observed morphology and kinematics indicate that 12CO emission is tracing an extended (~1000 au) molecular outflow, 13CO is tracing

the outer (∼1000 au) envelope/pseudo-disk regions, and C18O and 1.3 mm continuum emission are tracing the inner (∼500 au) pseudo-disk. In addition, we have observed the 10 µm silicate absorption spectrum for the proto-BD, which is indicative of crystalline enstatite and forsterite silicates. Crystallization was likely expedited in this system due to strong jet/outflow activity. We have built a 3D physical model to interpret the complex internal structure of the proto-BD. This proto-BD system is viewed through a wide outflow cavity, due to which the embedded core is hidden and the envelope/pseudo-disk regions are partially visible, while giving a direct view of the jet/outflow. The various signatures of the proto-BD system, in particular, the very young ∼616 yr outflow dynamical age, the high outflow rate of the order of 10-7 Msun/yr, and the comparable envelope and outflow sizes, are indicative of an early Class 0 stage system being formed via the mechanism of gravitational collapse of a very low-mass core.

The chemical composition of stars and their rotational evolution

Louis Amard (1); Julia M. T. Roquette (2); Sean Matt (3)

(1) University of Exeter; (2) University of Exeter; (3) University of Exeter

The spin-down of stars with time can be used as a tool to provide stellar ages under certain conditions. Large photometric surveys such as Kepler, TESS or even GAIA, thus relies on rotation period measurement to estimate the age of cool main sequence stars. However, this gyrochronology technique has so far been well tested and calibrated mostly on young stars of solar metallicity, while field stars are mostly relatively old and cover a broad range of chemical compositions. In this talk I will review the recent works on rotational evolution models of cool main-sequence stars, their chemical composition, and the consequences on age determination via gyrochronology. As an example, I will present a direct application of recent models on the Kepler field. I will finally discuss the direction on which progress towards a global stellar rotation model can be made and its role to play in the interpretation of future surveys.

Are the rotation period distributions in zero-age main sequence open clusters alike?

Dario J. Fritzewski; Sydney A. Barnes; David J. James; Klaus G. Strassmeier

Leibniz Institute for Astrophysics Potsdam (AIP), Leibniz Institute for Astrophysics Potsdam (AIP), Center for Astrophysics | Harvard & Smithsonian, Leibniz Institute for Astrophysics Potsdam (AIP)

The universality of stellar evolution is fundamental to our understanding of stars. The evolution of angular momentum can also be used to test this concept because rotation changes significantly with stellar age, and can be probed sensitively using stellar rotation periods.

We present new rotation periods measured from photometric time series observations for stars in the 150 Myr-old, zero-age main sequence open cluster NGC 2516. Among the members, selected using Gaia data, ground-based radial velocities, and multi-colour photometry, we find 308 stars with rotation periods which range from 0.25 d to 25 d. Combined with rotation period data for M dwarfs from the literature, a total of 555 periods for stars ranging from G to mid-M are now known in NGC 2516. This large sample enables a detailed comparison with the K2-based rotation period distribution constructed for the Pleiades and also the corresponding X-Ray activity diagrams.

Comparison between NGC 2516 and Pleiades shows that the two open clusters can be considered as twins because in addition to the classical parameters, their rotation period distributions are almost indistinguishable across the colour and period ranges. Both clusters also host a group of slowly-rotating M dwarfs with (P>15d), unseen before in other open clusters, that constitute what we call "the extended slow rotator sequence". Further comparison between NGC 2516 and the other nearly coeval open clusters M35, Blanco 1, and M50 shows that these rotation period distributions are also substantially similar to that for NGC 2516, at least to the extent that the limitations of the individual studies permit.

Based on empirical comparison of these five different open clusters, our study suggests that coeval open clusters of similar composition have identical rotation period distributions, the strongest evidence to data against cluster-to-cluster variations. We conclude that the star formation process in different cluster environments is likely universal enough to result in substantially identical rotation period distributions at the ZAMS.

The first 10 Gyr evolution of 'failed stars' as transitional and degenerate brown dwarfs

ZengHua Zhang

Nanjing University

Brown dwarfs (BD) are called 'failed stars', but are important on the study of exoplanets' ultracool atmospheres and constraint of the initial mass function. However, the BDs population is difficult to characterise. First because BDs cool/fade and change temperature/luminosity over time, and caused the mass-age degeneracy. Secondly, the existence of transitional BDs (T-BD) was ignored by most of observers, although it has been indicated by evolutionary models (e.g. Burrows+1993).

T-BDs formed a mass range of substellar transition zone (STZ), which separates very low-mass stars, T-BDs, and degenerate BDs (D-BD). T-BDs have unsteady hydrogen fusion in their cores to replenish the dissipation of their initial thermal energy, thus have extremely slow cooling rate. As the majority of BDs, D-BDs have no energy supply from hydrogen fusion, thus cool continuously. The STZ has a narrow mass range but could be stretched into a wide range of temperature/luminosity over time. Therefore, the STZ could be resolved in the metal poor BD population, which are all very old ($\sim$10 Gyr) but extremely rare.

In this talk, I will explain the different evolutions and properties of very low-mass stars, T-BDs and D-BDs. I will present the spectral type-colour correlations, spectral type-absolute magnitude correlations, colour-colour plots, and HR diagrams of L and T subdwarfs, in comparison to these of L and T dwarfs. I will show how metal-poor brown dwarfs lead us to new interpretation of evolutionary models, which in return help us to reach a better understanding of brown dwarf population.

This talk is based on works published in a series titled 'Primeval very low-mass stars and brown dwarfs' (https://ui.adsabs.harvard.edu/public-libraries/gVGomDWcQGyKPWw2CGg3dg).

Accretion and outflow activity in Class 0/I proto-brown dwarfs

B. Riaz (1); C. Briceno (2); S. Heathcote (3)

(1) USM, LMU; (2) NOAO, Chile; (3) NOAO, Chile.

Outflows actively contribute to the core collapse and formation of the star by carrying away the excess angular momentum that would otherwise prevent accretion. These processes shape the structure of the star during its early evolutionary stages. We have conducted the first survey to investigate the accretion and outflow activity in early-stage Class 0/I proto-brown dwarfs (proto-BDs), and to understand how these processes compare with the results for low-mass Class 0/I protostars. Our analysis is based on high-resolution VLT near-infrared IFU observations. The spectra for the proto-BDs have revealed several [FeII] and H2 lines along with the H I, Paschen-beta, and Bracket-gamma lines. He accretion and outflow activity rates for the proto-BDs show a wide range between 10^{-7} – 10^{-9} Msun/yr, resulting in the ratio of the activity rates or the jet efficiencies in the range of ∼0.007-0.06. The jet efficiency for the proto-BDs is comparatively lower than Class 0/I protosars (∼0.04- 0.1). Based on an analysis of the jet/outflow structure and kinematics in the spectro-images, we find evidence of two kinds of flows in proto-BDs: (i) low-velocity (<40 km/s) outflows that are compact (<0.01 pc) in length and wide (∼0.03-0.07 pc); (ii) high-velocity (>50 km/s) jets that are extended (>0.1 pc) and collimated (widths <0.01 pc). No particular difference is seen in the activity rates or the je morphology between Class 0 and Class I proto-BDs. I will present a comparison of our high-resolution observations with new jet/outflow models developed for proto-BDs that can help understand the similarities in the jet driving and propagation mechanisms in proto-BDs with protostars.

How underestimated are Zeeman-doppler imaging based torque estimates?

Victor See (1); Lisa Lehmann (2); Sean Matt (3); Adam Finley (4)

(1) University of Exeter; (2) University of Toulouse; (3) University of Exeter; (4) University of Exeter

Low-mass stars are known to spin-down over their main sequence life-times due to braking from magnetised winds. A key ingredient to estimating angular momentum-loss rates is the stellar magnetic field strength and geometry. These are parameters that Zeeman-Doppler imaging (ZDI) can provide. Although ZDI cannot recover the magnetic field associated with small-scale fields, this has not been thought to be a problem since the spin-down torque is dominated by large-scale magnetic fields. However, recent work indicates that ZDI also underestimates the magnetic flux in the large-scale fields. In this talk, I will discuss the amount by which torque estimates based on ZDI maps may be underestimated by.

Mapping the Accretion and Inner-Disk of Pre-Main-Sequence Stars with Emission Line Tomography

Justyn Campbell-White (1); Aurora Sicilia-Aguilar (2); Soko Matsumura (3); Veronica Roccatagliata (4)

(1) University of Dundee; (2) University of Dundee; (3) University of Dundee; (4) Universita di Pisa

Low- and intermediate-mass stars acquire most of their mass in the protostellar phase, but accretion continues into the pre-main-sequence phase via a disk for a few million years. Accretion governs the transport of matter and angular momentum from the accretion disk to the star. This affects disk stability and evolution, stellar rotation and activity, and planet formation and migration. The main observational challenge is probing the sub-au scales of the innermost disk, which is not yet possible via interferometry.

We have developed a set of automated tools to map the accretion activity and innermost disk of such stars using emission line tomography of time-resolved high-resolution spectra. This technique uses the time domain to look for distortions in the stellar emission line profiles and radial velocity signatures. We can then infer a tomographic map of the accretion structures, activity spots and the innermost hot atomic gas; down to smaller scales than those achievable with direct imaging. Our analysis allows for new science results to be obtained from archival data. We have also acquired new data to extend this approach for a statistically-significant and complete sample of stars for the first time. This allows us to explore the signatures, structure and magnitude of accretion, and how each property depends on stellar- and disk-type.

Our automated tools extract the accretion and/or activity spectrum from the high-resolution data, identify which atomic lines are present and characterise their properties. These tools would also be useful for different applications of spectral analysis where emission line identification is required. In this talk, we will present details of our automated tools, along with early results from our emission line tomography analysis.

Investigation in the long-term variations of the stellar activity indicators and their effect on radial velocity

Jean Costes; Christopher Watson; Andrew P. G. Thompson; Ernst J. W. de Mooij

Queen's University Belfast

Understanding stellar activity is crucial in the research of exoplanets. To confirm and measure the mass of Earth-analogue via the Doppler wobble technique, several years of observations will be required. However, monitoring stars on longer timescales presents difficulties for stellar-activity mitigation techniques. I will present long-term (similar to the 11-year cycle on the Sun) variation of activity levels and of different line-profile diagnostics for a multitude of stars, and show the impact they induce on RV measurements. By learning from their long-term trend, it is possible to mitigate RVs due to stellar activity with the aim to detect Earth's analogue.

Stellar wind torques in T Tauri stars: how to prevent spin-up?

George Pantolmos (1); Claudio Zanni (2); Jérôme Bouvier (3)

(1) Univ. Grenoble Alpes, CNRS, IPAG; (2) INAF - Osservatorio Astrofisico di Torino; (3) Univ. Grenoble Alpes, CNRS, IPAG

Classical T Tauri stars magnetically interact with their surrounding disks, a process that controls their rotational evolution. Observations reveal that these young stellar objects maintain a constant rotation in time, indicative of angular-momentum-loss mechanisms that prevent the stellar spin rate to increase due to both accretion and contraction. Various types of outflows, such as stellar winds, magnetospheric ejections, and disk winds have been proposed to explain this phenomenon. However, there are no conclusive answers to which is the fundamental process governing the angular-momentum transport in classical T Tauri systems. I will present a numerical study, which employs 2.5D MHD simulations and compares the magnetic braking, due to stellar winds, in two distinctive systems: isolated (i.e., weak-line T Tauri and main-sequence) and accreting (i.e., classical T Tauri) stars. In both systems, the stellar outflow is thermally driven and therefore, more suitable for torque-efficiency comparisons with magnetized winds from isolated stars. We find that stellar winds originated from classical T Tauri systems brake the stellar-surface rotation more efficiently compared to outflows from diskless stars. In the star-disk-interaction simulations, the stellar outflows extract less than 2% of the mass-accretion rate and up to about half of the accretion torque. Finally, we predict that a stellar wind ejecting around 5% of the mass-accretion rate is able to counteract the stellar spin-up due to accretion.

This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement No 742095; SPIDI: Star-Planets-Inner Disk-Interactions). http://spidi-eu.org/

Effects of the winds of host stars on the escaping atmospheres of close-in planets

Aline Vidotto; Stephan Carolan; Carolina Villarreal D'Angelo; Gopal Hazra; Andrew Cleary

Trinity College Dublin, Ireland

The atmospheres of highly irradiated exoplanets are observed to undergo hydrodynamic escape. However, due to strong pressures, stellar winds can confine planetary atmospheres, reducing or even preventing their escape. Here, we investigate under which conditions atmospheric escape of close-in giants could be confined by the large pressure of their host star's winds. For that we first conduct 1D simulations of escape in planets at a range of orbital distances ([0.04, 0.14] au), planetary gravities ([36%, 87%] of Jupiter's gravity), and ages ([1, 6.9] Gyr). Simultaneously, we derive the properties of the host star's wind for each planetary system. We show that, although younger close-in giants should experience higher levels of atmospheric escape, due to higher stellar irradiation, stellar winds are also stronger at young ages, potentially reducing escape in young exoplanets. Regardless of the age, we also find that there is always a region in our parameter space where atmospheric escape is confined by the stellar wind, preferably occurring at higher planetary gravities and orbital distances. We then conduct 3D simulations focusing on a subset of our large 1D sample, and calculate their spectroscopic transits. We show that stellar winds with larger mass-loss rates would act as to reduce the transit signature in hydrogen lines due to stronger confinement. We finally apply our models to some known exoplanets and conclude that the lack of hydrogen escape recently reported for pi Men c could be caused by the strong pressure of the wind of its host star.

Constraining the M dwarf age-activity relationship across the age of the Galaxy

Elena González Egea (1); Ben Burningham (2); Federico Marocco (3); Roberto Raddi (4)

(1) University of Hertfordshire; (2) University of Hertfordshire; (3) JPL/California Institute of Technology; (4) Universitat Politecnica de Catalunya

M dwarf (dM) stars are prime targets for exoplanet studies, but their magnetic activity and physical parameters are not well constrained yet. Activity in dMs decreases while they spin down over billions of years. This rotation-activity relation leads to an age-activity relationship, which we aim to constrain for ages up to 10 Gyr. Towards this goal, we are conducting a survey of dM + white dwarf (WD) wide binary systems identified in Gaia DR2, to use WDs as age calibrators. We have collected spectroscopic data for 29 binaries to determine the dMs spectral types, derive chromospheric activity proxies, and to infer the total age of the systems via evolutionary models to their WD companions. Additionally, we have collected radio and X-ray data of 9 close binaries from our sample to explore the dMs activity levels in these domains. We present here the first results of this project, which will allow us to significantly improve our understanding of the age-activity relation of older M dwarfs.

Forward modelling of stellar variability for active planet hosting stars

Luke J. Johnson (1); Charlotte M. Norris (2); Yvonne C. Unruh (3); Sami K. Solanki (4); Natalie Krivova (5); Veronika Witzke (6); Alexander I. Shapiro (7)

(1) Imperial College London; (2) Imperial College London; (3) Imperial College London; (4) Max Planck Institute for Solar System Research; (5) Max Planck Institute for Solar System Research;

(6) Max Planck Institute for Solar System Research; (7) Max Planck Institute for Solar System Research

Stellar variability is a dominant noise source in exoplanet surveys that can hinder the detection and characterisation of planets with active stellar hosts. Current lightcurve modelling efforts implement 1D models that do not fully capture the 3D nature of stellar photospheres and surface manifestations of magnetic activity such as dark spots and bright faculae. Models empirically constructed from solar observations are used to correct for this, but cannot be extrapolated to non Sun-like stars. We model the lightcurves of active late-type stars as they rotate, using emergent intensity spectra calculated from 3D magnetoconvection simulations of G, K and M-type stellar atmosphere regions at different viewing angles to reproduce centre-to-limb brightness variations. We present mean expected variability levels for several cases and compare with solar and stellar observations. We also investigate the effects of varying parameters such as filling factor, surface feature distribution and stellar inclination on the measured variability.

First Results from a New Multi-Wavelength Observing Campaign of Proxima Centauri

Meredith MacGregor (1); Rachel Osten (2); Evgenya Shkolnik (3); R. O. Parke Loyd (4); Alycia Weinberger (5); Ward Howard (6); Tom Barclay (7); Allison Youngblood (8); Adam Kowalski (9); Steven Cranmer (10); Andrew Zic (11); Tara Murphy (12); David Wilner (13); Anna Hughes (14); Aaron Boley (15); Jan Forbrich (16); Nicholas Law (17); Jaymie Matthews (18)

(1) University of Colorado Boulder; (2) Space Telescope Science Institute; (3) Arizona State University; (4) Arizona State University; (5) Carnegie Institution for Science; (6) University of North Carolina; (7) NASA Goddard; (8) University of Colorado Boulder; (9) University of Colorado Boulder; (10) University of Colorado Boulder; (11) University of Sydney; (12) University of Sydney; (13) Center for Astrophysics | Harvard & Smithsonian; (14) University of British Columbia; (15) University of British Columbia; (16) University of Hertfordshire; (17) University of North Carolina; (18) University of British Columbia

M dwarfs are the most abundant stars in the galaxy and have a high frequency of Earth-sized planets, making them favored targets of upcoming missions to detect and characterize exoplanets. However, these stars are known to exhibit high levels of activity and flaring, which could impact the habitability of planets around them. At a distance of only 1.3 pc, Proxima Cen is the closest extrasolar planetary system orbiting an M dwarf flare star, making it a benchmark case to explore the properties and potential effects of stellar activity. We previously discovered a flare from Proxima Cen at millimeter wavelengths with the Atacama Large Millimeter/submillimeter Array (ALMA), which has opened up an entirely new observational regime to study stellar flaring mechanisms. In this talk, I will present the first results from a new multi-wavelength observing campaign that monitored Proxima Cen for roughly 40 hours simultaneously with ALMA, the Hubble Space Telescope (HST), the Transiting Exoplanet Survey Satellite (TESS), the Neil Gehrels Swift Observatory, Chandra X-Ray Observatory, Evryscope, the du Pont telescope at Las Campanas, the Las Cumbres Observatory Global Telescope (LCOGT) 1m, and a complementary suite of Australian telescopes spanning radio to optical wavelengths. This is the first time that we have detected millimeter emission along with other wavelengths during an M dwarf flare– we now know that this emission is a common part of the flaring process. Intriguingly, millimeter emission appears to correlate closely with UV emission, while the optical brightness need not correspond to the brightness at other wavelengths and thus the true energy output of the event. The correlation between the FUV and millimeter emission suggests that these wavelengths directly trace the initial particle acceleration, while the delayed optical emission

likely comes from heated plasma that decays more slowly. The initial results from this campaign are already challenging our current theoretical models of stellar flaring. We expect to learn much more as we synthesize the rest of the available data.

The Chromosphere of Fainting Betelgeuse

Andrea Dupree for the MOB

Center for Astrophysics | Harvard & Smithsonian

During 2019 and 2020, HST/STIS made 8 visits to the supergiant to obtain spatially resolved spectra across the extent of the ultraviolet image. The velocity fields in the chromosphere change with time. The Mg II lines in the south east region became enhanced prior to the unexpected steep decline at visual magnitudes that occurred in December 2019 and January 2020. Mg II emission returned to previous levels in February 2020. We discuss models to explain this unusual behavior including information from contemporanous optical spectra.

Ages for Red Giant Stars Associated with Thick Disk and Stellar Halo Substructures

Samuel Grunblatt (1); Joel C. Zinn (2); Adrian Price-Whelan (3); Earl Bellinger (4); Nicholas Saunders (5); Sarah Martell (6); Ruth Angus (7)

(1) American Museum of Natural History & Flatiron Institute; (2) University of New South Wales; (3) Flatiron Institute & Princeton University; (4) Aarhus University; (5) University of Hawaii; (6) University of New South Wales; (7) American Museum of Natural History & Flatiron Institute

A large majority of the stars in the stellar halo of the Milky Way were likely accreted from smaller satellite galaxies. From kinematic and chemical information, it has been argued that most of the stellar mass in our Halo originated in a small number ($<\sim 3$) of relatively large dwarf galaxies. However, the timing of these merger events is poorly constrained, and to date has only been precisely studied using a handful of individual stars. However, many stars in these streams with extreme peculiar velocities and angular momenta have evolved into red giants and can thus be characterized (and age-dated) with asteroseismology using the all-sky photometric mission TESS. By combining asteroseismic and spectroscopic constraints, we have determined accurate stellar ages for kinematically peculiar red giant stars, and use these stars as benchmarks to calculate ages for similar stars with only asteroseismic information. Here, we present an asteroseismic analysis of 10 stars with velocities and angular momenta consistent with stellar halo or thick disk substructures, such as Gaia-Enceladus. We provide masses, radii, and ages for these 10 stars, and determine that all of the stars in our sample with negligible or retrograde angular momenta are relatively old, likely forming more than 8 Gyr ago. The ages of these stars indicate that the Gaia-Enceladus merger may have taken place at least 8 Gyr ago, and will provide useful benchmarks for understanding the accretion history of our Galaxy.

Exploring the solar paradigm to understand stellar variabilities

Nina-Elisabeth Nemec (1); Alexander I. Shapiro (2); Natalie A. Krivova (3); Emre Isik (4); Sami K. Solanki (5); Robert H. Cameron (6)

(1) Max-Planck- Institut für Sonnensystemforschung; (2) Max-Planck- Institut für Sonnensystemforschung; (3) Max-Planck- Institut für Sonnensystemforschung; (4) Max-Planck-Institut für Sonnensystemforschung/Turkish-German University; (5) Max-Planck- Institut für Sonnensystemforschung/Kyung Hee University; (6) Max-Planck- Institut für Sonnensystemforschung

The emergence of magnetic field on stellar surfaces leads to the formation of magnetic features, such as dark spots and bright faculae. These features cause stellar brightness variations. Such variations have been extensively studied for the Sun. The plethora of photometric data obtained by both past (e.g. CoRoT and *Kepler*) and current space missions (TESS and Gaia) have underlined the needs for a better understanding and modelling of stellar brightness variations. One of the possible approaches for such modelling is to rely on the solar paradigm, i.e. to take a model which reproduces the observed variability of the solar brightness and extend it to other stars.

We follow the SATIRE approach of calculating brightness variations, which was shown to reproduce the solar variability in great detail. To obtain the surface distribution of magnetic features, we employ a surface flux transport model. This allows extending the SATIRE calculations to stars with different rotation periods and inclinations. First, we apply our model to calculate solar variability as it would be measured by stellar missions, such as CoRoT, Kepler, TESS, and Gaia, and quantify the effect of the inclination on the variability. Our model indicates that cancellation of small-scale magnetic flux associated with faculae leads to the spot surface area coverage increasing faster with activity than the coverage by faculae. This provides a natural explanation for stellar variability on the activity-cycle timescale being facula-dominated in low-activity stars like the Sun and spot-dominated in more active stars. We also calculate the rotational variability of stars rotating faster than the Sun and compare it to Kepler and TESS observations.

How can we detect solar-like magnetic cycles with the Zeeman-Doppler-Imaging (ZDI) technique?

Lisa T. Lehmann (1); Gaitee A. J. Hussain (2); Aline A. Vidotto (3); Moira M. Jardine (4); Duncan H. Mackay (5)

(1) SUPA, School of Physics and Astronomy, University of St Andrews & Institut de Recherche en Astrophysique et Planétologie, Université de Toulouse, UPS-OMP; (2) European Southern Observatory & Institut de Recherche en Astrophysique et Planétologie, Université de Toulouse, UPS-OMP; (3) School of Physics, Trinity College Dublin, The University of Dublin; (4) SUPA, School of Physics and Astronomy, University of St Andrews; (5) School of Mathematics and Statistics, University of St Andrews

We are reaching the point where our spectropolarimetric surveys run long enough to observe solar-like magnetic activity cycles. But what would be the best strategy to detect magnetic cycles similar to the one of our Sun and which magnetic field parameters best follow a solar-type magnetic cycle with the large scale magnetic field maps obtained using ZDI? I will answer these questions using the 3D non-potential flux transport simulations of Yeates & Mackay (2012) modelling the solar vector magnetic field over 15 years (centred on solar cycle 23). The flux emergence profile was extracted from solar synoptic maps and used as input for a photospheric flux transport model in combination with a non-potential coronal evolution model. We synthesise spectropolarimetric data from the simulated maps and reconstruct them using ZDI. From our analysis of the reconstructed ZDI maps, I will present guidelines to detect solar-like cycles using a parameter-based analysis of the evolving magnetic field topology. In addition, we set the ZDI observed solar cycle into the context of other cool stars observations and present observable trends of the magnetic field topology with S-Index and X-ray flux, which will help to identify a second Sun in terms of magnetic cycle activity.

From the Inner to Outer Milky Way: A Pristine Sample of 4.3 Million Red Clump Stars

Madeline Lucey (1); Yuan-Sen Ting (2); Nesar Ramachandra (3); Keith Hawkins (4)

(1) University of Texas at Austin; (2) Institute for Advanced Study/Princeton/Observatories of the Carnegie Institution of Washington; (3) Argonne National Lab; (4) University of Texas at Austin

Large pristine samples of red clump stars are highly sought after given that they are standard candles and give precise distances even at large distances. Recently, it was shown that the asteroseismic parameters, period spacing (ΔP) and frequency separation ($\Delta \nu$), which are used to accurately select red clump stars, can be derived from spectra using the change in the surface carbon to nitrogen ratio ([C/N]) caused by mixing during the red giant branch. This change in [C/N] can also impact the spectral energy distribution. In this study, we predict the ΔP, $\Delta \nu$, T_{eff} and log g using 2MASS, AllWISE, Gaia, and Pan-STARRS data in order to select a clean sample of red clump stars. Training on a sample with known parameters, we achieve a contamination rate of $\sim$20%, equivalent to what is achieved when selecting from T_{eff} and log g derived from low resolution spectra. Finally, we present two red clump samples. One sample has a contamination rate of $\sim$20% and $\sim$ 510,000 red clump stars. The other has a contamination of $\sim$ 35% and $\sim$ 4.3 million red clump stars which includes over 280,000 stars at distances > 10 kpc. The scientific potential of this catalog for studying the structure and formation history of the Galaxy is vast given that it includes millions of precise distances to stars in the inner bulge and distant halo where astrometric distances are imprecise.

The IGRINS YSO Survey: Stellar parameters of pre-main sequence stars in Taurus-Auriga

Ricardo López Valdivia; Greg Mace; Dan Jaffe

The University of Texas at Austin

We present fundamental parameters for 131 K & M type Young Stellar Objects observed with theImmersion GRating INfrared Spectrometer (IGRINS). The class II and class III objects in the survey are canonical Taurus-Auriga members. With broad spectral grasp (1.45-2.5μm) at high resolution(R$\sim$45,000), IGRINS spectra permit the simultaneous determination of effective temperature, surface gravity, magnetic field strength, projected rotational velocity and continuum veiling. Our method employs synthetic spectra and a Markov chain Monte Carlo approach to fit specific H- and K-band spectral regions most sensitive to those parameters. We consider our measurements to be more accurate and precise than those in the literature because strong absorption lines are modified by magnetic fields, which can result in modified effective temperature and surface gravity at the 3σ level . We do not find any significant difference in the average stellar parameters for the class II and class III objects in our sample, which underscores the uncertainty in the evolutionary sequence of these classifications and implies that differences are in characteristics rather than age.

Legacy catalog of surface rotation, photometric activity, and active-region (lower-limit) lifetimes of solar-type stars observed by Kepler

A. R. G. Santos (1); S. Mathur (2); R. A. García (3); S. N. Breton (4); J. van Saders (5); R.

Egeland (6); L. Bugnet (7); T. S. Metcalfe (8); G. V. Simonian (9); M. H. Pinsonneault (10)

(1) Space Science Institute; (2) Instituto de Astrofísica de Canarias; (3) IRFU/CEA/Université Paris-Saclay; (4) University of Hawai'i; (5) High Altitude Observatory; (6) The Ohio State University

Brightness variations due to dark magnetic spots encode information about stellar surface rotation and magnetic activity. We analyze ∼160,000 main-sequence and subgiant solar-type stars (from spectral type M to the instability strip) observed by the Kepler main-mission in order to retrieve their average values of surface rotation and photometric activity. We start by identifying and removing contaminants from the sample, such as light curves exhibiting photometric pollution, classical pulsators candidates, and misclassified red giant stars. We analyzed four data sets obtained with different calibration pipelines and different low-pass filters. This is of extreme importance to find the right balance between filtering Kepler instrumental modulations and filtering the intrinsic stellar signal. For each time series we obtain three rotation estimates through a combination of wavelet analysis and the autocorrelation function of light curves. Reliable rotation periods are determined by comparing the rotation estimates obtained from the different diagnostics and time series, and, in particular, to deal with the large number of targets, by implementing machine learning algorithms. While removing contaminants that were previously considered in rotational analyses, we increase significantly the number of known rotation periods, particularly in comparison with the previous largest rotation catalog by McQuillan et al. (2014; an increase of 20% for KM dwarf stars in Santos et al. 2019). We are able to extend the analysis to fainter and cooler stars and we report periods for subgiants in addition to main-sequence targets. For stars with retrieved rotation period we further investigate the photometric activity and variability, and the timescale of the autocorrelation function, related to active-region lifetimes, which is first scrutinized using artificial data. This analysis leads to the largest sample of stars with reliable rotation periods with a wide range and level of activities that will not be increased by near future missions.

Studying the atmosphere of the close binary star system AADor with simulation code phoenix/1D

Fiona Prodöhl; Peter H. Hauschildt

Universität Hamburg

Synthetic spectra from model atmospheres are frequently used in the analysis of observed spectroscopic and photometric data. For the most part, the models are sufficiently detailed to test the current theoretical understanding of stellar and sub-stellar mass objects at various stages in their evolution. However, the vast majority of model atmospheres are constructed under the assumption that the nearest stellar neighbor is so far away that it can be safely ignored. This assumption, while safe for most stars, fails for many short period binaries. A number of binary systems have orbital separations small enough so that one of the binary members is significantly heated by its companion. In order for synthetic spectra to be useful in such cases, the standard "isolated" modeling approach must be replaced by one that includes the effects of irradiation. The AADor system is an excellent example of a well-studied non-mass transferring Post-common envelope binary system. Its members are a sdOB-type primary and an extremely low mass secondary. This work is aiming to provide better theoretical models by using spherical models. We investigate how several 1D models combined to a 1.5D model can represent this system. Our future aim is to compare these results to a phoenix/3D model that is able to include effects of irradiation closer to the terminator where transmitting light plays a big role.

Coronal Dimming as a Proxy for Stellar Coronal Mass Ejections

Meng Jin (1); Mark C. M. Cheung (2); Marc L. DeRosa (3); Nariaki V. Nitta (4); Carolus J. Schrijver (5); Kevin France (6); Adam Kowalski (7); James P. Mason (8); Rachel Osten (9)

(1) SETI Institute; (2) Lockheed Martin Solar and Astrophysics Lab (LMSAL); (3) Lockheed Martin Solar and Astrophysics Lab (LMSAL); (4) Lockheed Martin Solar and Astrophysics Lab (LMSAL); (5) Lockheed Martin Solar and Astrophysics Lab (LMSAL); (6) Laboratory for Atmospheric and Space Physics, University of Colorado at Boulder; (7) Laboratory for Atmospheric and Space Physics, University of Colorado at Boulder; (8) Laboratory for Atmospheric and Space Physics, University of Colorado at Boulder; (9) Space Telescope Science Institute

Solar coronal dimmings have been observed extensively in the past two decades and are believed to have close association with coronal mass ejections (CMEs). Recent study found that coronal dimming is the only signature that could differentiate powerful flares that have CMEs from those that do not. Therefore, dimming might be one of the best candidates to observe the stellar CMEs on distant Sun-like stars. In this study, we investigate the possibility of using coronal dimming as a proxy to diagnose stellar CMEs. By simulating a realistic solar CME event and corresponding coronal dimming using a global magnetohydrodynamics model (AWSoM: Alfvén-wave Solar Model), we first demonstrate the capability of the model to reproduce solar observations. We then extend the model for simulating stellar CMEs by modifying the input magnetic flux density as well as the initial magnetic energy of the CME flux rope. Our result suggests that with improved instrument sensitivity, it is possible to detect the coronal dimming signals induced by the stellar CMEs.

Young and Active: Mass and Obliquity Constraint of the Neptune-sized Planet K2-25b

HPF Team

HPF Team

Young planetary systems with known ages are benchmarks to constrain the early stages of planet formation. The 3D orbital properties of these systems are direct tracers of their formation history and subsequent dynamical interactions. Using the newly commissioned near-infrared Habitable-zone Planet Finder (HPF) spectrograph, we report the mass, eccentricity, and obliquity constraint of the K2-25b planetary system. The Neptune-sized planet K2-25b orbits its M4.5-dwarf host star in the young (650-800Myr) Hyades cluster at a short period of 3.5 days. At a mass of 25 Earth masses and radius of 3.44 Earth radii, a two-component composition model assuming a rocky core encapsulated by a H/He envelope, suggests a H/He envelope mass fraction of $\sim$5%. Using precision RVs from HPF along with precision transit photometry, we show that K2-25b has a moderate eccentricity of 0.4, and is likely in the progress of circularizing its orbit via tidal interactions with the host star. Finally, three Rossiter-McLaughlin (RM) observations of this system with HPF show that the orbit is well-aligned with the stellar equator, placing further constraints on the formation and dynamical evolution of this system. K2-25b is currently the youngest M-dwarf planetary system with a measured mass and obliquity, yielding insights into the formation and evolution of planets orbiting low-mass stars; K2-25b could represent a precursor to other hotter Neptune-sized planets which have had the time to circularize their orbit and migrate closer to their older host stars.

Yellow straggler stars and spectroscopic age indicators in the young stellar association AB Doradus

Leandro O. Kerber

Universidade Estadual de Santa Cruz UESC

We have done a high-resolution spectroscopic analysis of binary and non-binary dwarf stars within AB Doradus. This association is one of the 9 nearby young stellar associations identified in the SACY project (Torres et al. 2003a, b). To carry out our study, we have applied the LTE-hypothesis by means of the Kurucz atmospheric grids and spectral code MOOG. The spectra were observed with the spectrograph FEROS (R = 45000) installed in the 2.2 mts telescope/La silla, we have also obtained spectra from ESO/archive. We have calculated stellar atmospheric parameters and chemical abundances. Our results shown that there are Yellow Straggler Stars (YSS) in AB Doradus. These type of stars were reported in first time by Sales Silva et al. (2014), YSS present a systematic decreasing in the depth of the absorption lines. This effect, called veiling, produces in turn changes of the abundance ratios relative to the another member stars of the association. We have also derived the abundance ratios [Y/Mg] and [Y/Al] that have been proposed as promissory spectroscopic age indicators for solar analogue and field dwarf stars. Stars within young associations are on the Zero Age Main Sequence (ZAMS), that is to say they are chemically homogeneous and therefore an excellent scenario to study these age indicators. Using our [Y/Mg] and [Y/Al] we have obtained ages of 132 Myr and 175 Myr respectively, that are similar to the AB Doradus's age reported by Bell et al. (2015). We conclude that the best hypothesis to explain the veiling detected in the spectra is to propose that these stars are in binary or multiple systems. In this scenario, the companion stars contaminated the YSS spectra, producing the detected behavior in the chemical abundances. In the same way than for main sequence stars, we confirm that [Y/Mg] and [Y/Al] also work as age indicators for ZAMS stars.

3D MHD Simulations of Accretion onto Magnetized Young Stars

Shinsuke Takasao (1); Kazunari Iwasaki (2); Kengo Tomida (3); Takeru K. Suzuki (4)

(1) Osaka University; (2) National Astronomical Observatory of Japan; (3) Tohoku University; (4) University of Tokyo

Young stars grow via the interaction with accretion disks. The star-disk interaction plays crucial roles in determining the stellar evolution and the inner disk structure. We have been developing 3D MHD star-disk models to reveal the accretion process in the vicinity of a central star (Takasao et al. 2018, 2019). We present our new results of magnetospheric accretion. We investigated magnetospheric accretion using 3D MHD simulations with the highest spatial resolution ever. Our model captures both the disk turbulence caused by magneto-rotational instability (MRI) and the disk wind driven by MRI turbulence, which was not succeeded in the previous models. We found that funnel accretion flows originate not only from the magnetospheric boundary but also from the disk wind. Namely, part of the slow turbulence-driven disk wind fails to escape from the disk and falls onto the star. At the magnetospheric boundary, magneto-centrifugally-driven wind is launched as a reaction of magnetospheric accretion. Accretion flows penetrate the magnetosphere in a spatially and temporally intermittent way. As a result, the centrifugally-driven wind becomes highly time-variable. In this paper, we will discuss the accretion structure and the angular momentum transport.

Large Adaptive optics Survey for Substellar Objects (LASSO)

Maissa Salama (1); James Ou (2); Christoph Baranec (3); Michael C. Liu (4); Brendan P. Bowler (5); Paul Barnes (6); Morgan Bonnet (7); Mark Chun (8); Dimitry A. Duev (9); Don Hall (10); Shane Jacobson (11); Rebecca Jensen-Clem (12); Shrinivas R. Kulkarni (13); Nicholas M. Law (14); Charles Lockhart (15); Reed Riddle (16); Heather Situ (17); Eric Warmbier (18)

(1) IfA/University of Hawaii; (2) IfA/University of Hawaii; (3) IfA/University of Hawaii; (4) IfA/University of Hawaii; (5) University of Texas at Austin; (6) IfA/University of Hawaii; (7) IfA/University of Hawaii; (8) IfA/University of Hawaii; (9) California Institute of Technology; (10) IfA/University of Hawaii; (11) IfA/University of Hawaii; (12) University of California, Santa Cruz; (13) California Institute of Technology; (14) University of North Carolina at Chapel Hill; (15) IfA/University of Hawaii; (16) California Institute of Technology; (17) IfA/University of Hawaii; (18) IfA/University of Hawaii

We report on results from 450 observations of young, nearby, low-mass field stars for the Large Adaptive optics Survey for Substellar Objects (LASSO). LASSO is a large infrared AO direct imaging survey searching for wide orbit (>50 AU) massive exoplanets and brown dwarfs as companions around young, nearby, low-mass stars. The occurrence rates of these rare substellar companions are critical to furthering our understanding of planetary and stellar formation and evolution, as well as to clarify the boundary between massive exoplanets and brown dwarfs. The observations reported here were conducted with Robo-AO on the 2.1-m telescope on Kitt Peak, Arizona, from 2017-2018, then on the UH 2.2-m telescope on Maunakea starting in 2019. We identified $\sim$90 companion candidates within 5-400 AU separation range and up to 6.5 magnitude contrasts in the infrared. Robo-AO obtained simultaneous optical and infrared diffraction-limited resolution images, which provided us with limits or estimates on companion candidate colors, and thus temperatures. We also report on the sensitivity, performance, and data reduction process for the low-noise high-speed SAPHIRA near-infrared detector used with Robo-AO.

The dissolution of star clusters and the formation of wide binaries

Julio Chanamé (1); César Guerra (2)

(1) Pontificia Universidad Católica de Chie; (2) Pontificia Universidad Católica del Perú

Most clusters and associations do not live long and end up dissolving into the Galactic field. I will reassess what theory and observations have tought us about cluster dissolution by discussing new N-body models that are specifically tailored to closely follow stars as they leave their parent cluster and potentially giving rise to the population of very wide stellar binaries. These wide binaries are ubiquitous in the Galaxy, they are extremely useful for a large variety of astrophysical applications, and nowadays we keep learning about their properties and populations thanks to Gaia's precision astrometry. How exactly they have formed, however, remains as an open question, and no canonical, widely-accepted formation model really exists yet. In this context, N-body simulations have suggested that they could be formed during the dissolution phase of low-mass star clusters and associations. These models, however, make a number of assumptions that are unrealistic and/or arbitrary, especially in their treatment of the process of cluster dissolution and by ignoring the environment in which they live. To better understand the formation of wide binaries, we use N-body simulations to carefully follow shells of the cluster as it expands, and we consider escaping stars or binaries only in relation to the field external to the cluster and its mean background density. For a suite of simulations with varying initial conditions on cluster mass, size, and virial state, we compare the statistics of the binaries obtained in this way to previous work and the most recent observations

of wide binaries in the Galactic field. Our procedure allows us to identify key aspects of the physics of this formation channel that cannot be followed by more simplified models, thus offering insight on how to better understand the formation of these intriguing systems. Moreover, we study the possibility of using the observed properties of a population of wide binaries in order to infer the mass and size distribution of the population of extinct star clusters that originated those wide binaries.

Magnetic Mapping of Young Suns: Comparing Codes

Stephen Marsden (1); Jyri Lehtinen (2); Thomas Hackman (3); Sandra Jeffers (4); Oleg Kochukhov (5)

(1) University of Southern Queensland, Australia; (2) Max Planck Institute for Solar System Research, Germany; (3) University of Helsinki, Finland; (4) Georg-August-University Goettingen, Germany; (5) Uppsala University, Sweden

Mapping the surface magnetic fields of solar-type stars is one of the few ways in which we can study the dynamos of stars like our own Sun at differing evolutionary states. Recently we have obtained high-resolution spectropolarimetric data for a number of young Suns from HARPSpol on the 3.6-m telescope at La Silla. As part of the analysis of the magnetic fields of these stars we have decided to use these high-quality datasets to compare the magnetic and brightness maps produced from two independently developed magnetic mapping codes to study the robustness of the recovered maps. This presentation will compare the results from two of the young Suns observed, AH Lep and Kappa Ceti.

Multi-wavelength space weather monitoring of Proxima Centauri

Tara Murphy (1); Christene Lynch (2); Emil Lenc (3); George Heald (4); Meredith MacGregor (5); David L. Kaplan (6); Bruce Gendre (7); David Coward (8); Michael Wheatland (9); Adam Stewart (10); Dougal Dobie (11); Hao Qiu (12); Helen Johnston (13)

(1) The University of Sydney/CSIRO Astronomy and Space Science; (2) The University of Sydney; (3) International Centre for Radio Astronomy Research; (4) CSIRO Astronomy and Space Science; (5) CSIRO Astronomy and Space Science; (6) University of Colorado Boulder; (7) University of Wisconsin Milwaukee; (8) University of Western Australia; (9) University of Western Australia; (10) The University of Sydney; (11) The University of Sydney; (12) The University of Sydney/CSIRO Astronomy and Space Science; (13) The University of Sydney/CSIRO Astronomy and Space Science; (14) The University of Sydney

M-dwarfs are the most populous type of star in the Galaxy, and a large number of these stars are expected to hold planets within their habitable zones. At the same time, active M-dwarfs frequently produce flares several orders of magnitude more energetic than Solar flares. Associated effects, such as increases in ionising radiation, and frequent impacts of space weather events including coronal mass ejections (CMEs) may threaten the habitability of any planetary companions around these stars. While the radiative component of M-dwarf flares are routinely detected and characterised, the occurrence and nature of space weather events around these stars remains observationally unconstrained. In this talk, I will present results from a simultaneous radio and optical campaign targeting our nearest neighbouring star and terrestrial planet host, Proxima Centauri. Photometric monitoring with TESS and the Zadko 1m telescope reveals an energetic and long-duration flare, with an energy of $\sim 10^{31}$ erg. Simultaneous radio monitoring with the Australian Square Kilometre Array Pathfinder (ASKAP) shows a coherent, elliptically polarised burst occurring at the onset of the optical flare – the first example of a coherent radio burst directly associated with an optical flare from an active

M-dwarf. This initial radio burst was followed by a 5-hour long, 100% polarised, slowly drifting radio event. The properties of this event allow us to identify it as a Type IV burst - the first identification of a Solar-like burst event from an active M-dwarf. I will discuss the physical origin of this radio emission, and the implications of this event on the space weather around Proxima Centauri. Together, these results represent the clearest example yet of low-frequency Solar-like activity occurring on another star, and hint at the occurrence of energetic CMEs around our nearest stellar neighbour.

The variable nature of the chromosphere and transition region of the M dwarf GJ 436

Leonardo A. dos Santos; David Ehrenreich; Vincent Bourrier for the HST PanCET Team

University of Geneva

The Hubble Space Telescope is rarely used for long-term monitoring of astronomical objects given its observing time pressure and capabilities. However, in the case of the inactive M dwarf GJ 436, it has been observed so many times across several years, that we are able to see how magnetic activity and rotational modulation affects its far-ultraviolet (FUV) spectrum, which traces its transition region and chromosphere. In this contribution, I will present some of the puzzling results we observed for this star: an unexpectedly high flare rate in FUV, the blueshifted flare excess and long-lived activity regions that last for more than 60 rotations. Finally, we found an episodic redshifted absorption signal in the stellar Lyman-alpha emission that seems to be related to the transit of the planet GJ 436 b, but we struggle to explain in the framework of planetary atmospheres.

Tidal evolution of short-period planetary systems along the evolution of differentially rotating magnetic low-mass stars

Aurélie Astoul (1); Stephane Mathis (2); Clément Baruteau (3); Junho Park (4); Florian Gallet (5); Antoine Strugarek (6); Kyle C. Augustson (7); Allan Sacha Brun (8); Emeline Bolmont (9)

(1) Laboratoire AIM, CEA/DSM – CNRS - Univ. Paris Diderot – IRFU/DAp, Centre de Saclay; (2) Laboratoire AIM, CEA/DSM – CNRS - Univ. Paris Diderot – IRFU/DAp, Centre de Saclay; (3) Institut de recherche en astrophysique et planétologie, Université Toulouse III - Paul Sabatier, Observatoire Midi-Pyrénées; (4) Laboratoire AIM, CEA/DSM – CNRS - Univ. Paris Diderot – IRFU/DAp, Centre de Saclay; (5) Institut de Planétologie et d'Astrophysique de Grenoble; (6) Laboratoire AIM, CEA/DSM – CNRS - Univ. Paris Diderot – IRFU/DAp, Centre de Saclay; (7) Laboratoire AIM, CEA/DSM – CNRS - Univ. Paris Diderot – IRFU/DAp, Centre de Saclay; (8) Observatoire Astronomique de l'Université de Genève, Université de Genève; (9)

Over 4000 exoplanets have been discovered in the past 25 years or so, most of which orbit around low-mass stars. Star-planet tidal interactions are known to drive the late evolution of the shortest-period planetary systems. In particular, the dissipation of stellar tides changes the semi-major axis and the stellar spin on secular timescales. Such dissipation is known to vary considerably with the mass, age, rotation, and metallicity of the star. To draw a comprehensive picture of tidal dissipation in stars, two key physical mechanisms need to be further explored: stellar differential rotation and magnetism. Low-mass stars are indeed differentially rotating and magnetically active, as constrained by ground-based spectropolarimetric observations as well as space-based asteroseismic observations. In this rich observational context, recent theoretical investigations have shown that both differential rotation and magnetic effects can dramatically change the dynamics and dissipation

of tidal waves. In particular, a strong dissipation can occur due to angular momentum exchanges between tidal waves and zonal flows at so-called critical layers, where the orbital frequency is proportional to the local angular frequency of the fluid, with the possibility that this interaction becomes unstable. Also, Ohmic diffusion can largely compete with the turbulent viscous dissipation of tidal waves. In this contribution, I will report our recent progress on the investigation of these complex phenomena along the evolution of low-mass stars. First, by developing a local shearing box model, I will show how tidal waves can be either fully transmitted, damped, or even amplified at critical layers, with potentially strong implications for the evolution of planetary systems. Also, I will show how stellar magnetism deeply impacts the dissipation mechanism of tidal waves in the convective envelope of all low-mass stars all along their evolution. To obtain this important result for tidal modelling, we have used in synergies the physics of tidal magneto-inertial waves, scaling laws from the dynamo theory that allow us to estimate the amplitude of the large-scale magnetic field, and grids of stellar evolution models. I will finally discuss our strategy to model in a near future the tidal evolution of short-period systems orbiting around magnetically active and differentially rotating low-mass stars, using the observational constrains that we now have in hand.

Numerical simulations of convective core boundary mixing in low and intermediate mass stars.

Isabelle Baraffe

(1) University of Exeter; (2) CRAL-ENS Lyon

Convective boundary mixing (also known as "overshooting") is ubiquitous in stellar evolution. It is a necessary ingredient in stellar models in order to match a wide range of observations. Mixing at the boundary of convective cores in particular is an important source of uncertainty affecting all phases of evolution of low/intermediate mass stars, during main and post-main sequence (red giant, AGB) stages. How the efficiency of overshooting scales with stellar mass and stage of evolution is still very poorly known. I will present the first step towards addressing this key question with a numerical study of convective cores for a range of low/intermediate mass stars based on our multi-dimensional fully time implicit hydrodynamical code MUSIC. I will show our first results towards the derivation of a scaling law for the overshooting width and the mixing efficiency above a convective core as a function of stellar mass and luminosity.

The K Dwarf Advantage: Assessing the Habitability of Planets Orbiting K Stars

Tyler Richey-Yowell (1); Evgenya Shkolnik (2); Adam Schneider (3); R. O. Parke Loyd (4); Ella Osby (5); Travis Barman (6); Victoria Meadows (7)

(1) Arizona State University; (2) Arizona State University; (3) Arizona State University; (4) Arizona State University; (5) Arizona State University; (6) University of Arizona; (7) University of Washington

Knowing the UV emission of a star during a planet's formation and evolution is critical in determining if that planet is potentially habitable and if any biosignatures could be detected, as UV radiation can severely change or destroy a planet's atmosphere. Current efforts for finding a potentially habitable planet lie with M stars, yet K stars may offer more habitable conditions due to decreased stellar activity and more distant and wider habitable zones. In this talk, we will discuss our work to characterize both the quiescent and flaring UV evolutions of K stars using Galaxy Evolution Explorer (GALEX) photometry and Hubble Space Telescope (HST) spectroscopy. We will compare the evolution of

the high-energy radiation environments around K stars to that of M and G stars and examine the implications for these types of stars as hosts of potentially habitable planets.

X-ray and EUV Exoplanet Transits

Drake, J. J. (1); Kashyap, V. (2); Poppenhager, K. (3); Wolk, S. (4); Wargelin, B. (5)

(1) Smithsonian Astrophysical Observatory; (2) Leibniz Institute for Astrophysics, Potsdam, Germany; (3) Smithsonian Astrophysical Observatory; (4) Smithsonian Astrophysical Observatory

The evolution of planetary atmospheres is one of the most uncertain aspects of exoplanetary astrophysics. Successful models require knowledge of atmospheric source and loss terms and of how they change on a large range of timescales, from days to Gyrs. Atmospheric loss is in principle a tractable problem, depending on planetary characteristics such as orbit, magnetic field, rotation period and atmospheric chemical composition, and on the host star photon and particle radiation properties that drive the loss. In practice, the coupled physics and chemistry involved are extremely complex and likely require sophisticated time-dependent 3D models to treat properly. An alternative observational approach that has been pursued in the ultraviolet is to use planetary transits to detect the escaping gas in absorption against the stellar background light. Here, we highlight the utility of the soft X-ray and EUV bands for such measurements. We show that X-ray and EUV transit observations of close-in gas giants are a potentially powerful means of exploring planetary atmospheres and measuring scale heights, outflows and inferring chemical compositions. The required measurements could be obtained with either next-generation flagship missions, or with repeated observations by much more modest small satellite missions.

K2-136c: The Smallest Open Cluster Planet Mass Ever Measured

Andrew Mayo (1); Courtney Dressing (2); Annelies Mortier (3); Eric Lopez (4); Marcel Agüeros (5); Evgenya Shkolnik (6); Stephanie Douglas (7); Rose Gibson (8); The HARPS-N collaboration (9)

(1) University of California, Berkeley; (2) University of California, Berkeley; (3) Cavendish Laboratory, University of Cambridge; (4) NASA Goddard Space Flight Center & GSFC Sellers Exoplanet Environments Collaboration; (5) Columbia University; (6) Arizona State University; (7) Center for Astrophysics | Harvard & Smithsonian; (8) Columbia University; (9)

Young stars with known, well-constrained ages are excellent laboratories for studying the formation and early evolution history of orbiting planets. They provide a valuable snapshot that can bridge the temporal gap between the youngest planets (in protoplanetary disks) and settled, "middle-age" planets (which constitute the majority of discovered exoplanets). Additionally, because young stars tend to be more active, they provide insights into the relationship between the composition and characteristics of a planet and the stellar activity of its host star. K2-136 is a star in the Hyades with three known planets and an age of 790 ± 30 Myr. The planets (b, c, and d) have periods of 8.0, 17.3, 25.6 days and radii of 0.99 ± 0.05, 2.91 ± 0.11, 1.45 ± 0.10 $R_\oplus$, respectively. We collected radial velocity measurements with the HARPS-N spectrograph and found a semi-amplitude for planet c of 4.80 ± 0.73 m s^{-1}, from which we determined its mass to be 15.9 ± 2.4 $M_\oplus$. We also placed 95% upper mass limits on planets b and d of 2.67 and 6.47 $M_\oplus$, respectively. Further, we acquired and analyzed HST observations to establish the UV environment for these planets and investigate possible atmospheric loss. K2-136c is now the smallest planet to have a measured mass in an open cluster, as well as one of the youngest planets ever with a mass measurement. Curiously, the planet is quite dense for its size: $\sim 75\%$ the radius of Neptune but roughly the same mass, and therefore

twice as dense. This research and future mass measurements of similar open cluster planets will shed light on the compositions and characteristics of small exoplanets at a very early stage of their lives and provide insights into how exoplanets evolve with time.

Possible scenarios of Li enhancement in giant stars observed in 17 open clusters

M. Tsantaki (1); E. Delgado-Mena (2)

(1) Osservatorio di Arcetri/INAF; (2) Institute of Astrophysics and Space Sciences

Lithium is expected to be fully depleted in red giants due to the dilution they experience during their first dredge-up. However, several Li-rich giants have been observed in the field as well as in clusters with their origin still under discussion. In this work, we explore the Li content of giant stars in 17 different open clusters with high-resolution spectroscopy from the La Silla facilities with the HARPS spectrograph (Tsantaki et al. 2020, in prep.). This work is based on the planet search program around giant stars in clusters (Lovis & Mayor 2007, Delgado-Mena et al 2016).

We used the spectral synthesis technique (Tsantaki et al. 2018) to obtain Li abundances for 157 giant stars and provide criteria on evaluating upper limits and exact values for a precise analysis. We have found 6 red giants showing clear Li enhancement in 3 open clusters. We also calculated their masses, radii and luminosities by using the PARSEC isochrones (Bressan et al. 2012) and the Gaia DR2 parallaxes to infer their approximate evolutionary stage. Our Li-rich stars occupy different regions in the HR diagram. In some cases, they lie near the luminosity bump, where Li is produced by the Cameron-Fowler mechanism and fresh Li is brought to the surface by this extra mixing. In other cases, these stars are more evolved in the He-burning phase, or approach the asymptotic giant branch (AGB).

Since our targets are part of the planet search program, some of them have been detected with sub-stellar companions (Delgado-Mena et al. 2018, 2020 in prep.). An interesting scenario we evaluate in this work, is the possibility that Li enhancement is triggered by the engulfment of a close-in planet which initiates the extra-mixing process.

Kernel-Phase Interferometry for Super-Resolution Detection of Faint Companions

Adam L. Kraus

The University of Texas at Austin

Filling out the dearth of detections between directly imaged and radial velocity planetary mass companions (PMCs) will test theories of planet and low-mass star formation across the full range of semi-major axes, connecting formation of close to wide separation gas giants, and also substellar companions. Direct detection of close-in companions is notoriously difficult: coronagraphs and point spread function (PSF) subtraction techniques are significantly limited in separation and contrast. Non-redundant aperture masking interferometry (NRM or AMI) can be used to detect companions well inside the PSF of a diffraction limited image, though the technique is severely flux-limited since the mask discards $\sim$95% of the gathered light. Kernel-phase analysis applies similar interferometric techniques to an unobscured diffraction limited image, simulating the full telescope aperture as an interferometer composed of a grid of subapertures and calculating self-calibrating phase-like observables (similar to closure-phases used with NRM). I have developed a new faint companion detection pipeline which analyzes kernel-phases utilizing Bayesian model comparison. I break open the black box of interferometry by demonstrating the use of this pipeline on a large sample of HST/NICMOS images of nearby brown dwarfs, refining astrometry of previously known companions and searching for new companions. I also characterized the detection limits of this technique, demonstrating significant sensitivity down to flux ratios of $\sim 10^2$ at half λ/D, reaching the planetary-mass regime for young targets. I am now using this technique to search for PMCs in HST/ACS imaging of the young star-forming regions of Taurus and Upper Scorpius. Past (classical) image analysis was only sensitive to wide (∼40 au) PMCs, but we will find companions down to ∼5 au, an orbital range where some young PMCs have been discovered with more classical techniques around the limited number of very nearby young brown dwarfs. Since JWST will be able to perform NRM and unobscured imaging, further development and characterization of kernel-phase analysis will allow efficient use of competitive JWST time.

Activity and rotation of a primary CoRoT target HD43587

Rafael Ferreira (1); Rafaella Barbosa (2); Matthieu Castro (3); Gustavo Guerrero (4); Leandro de Almeida (5); Patrick Boumier (6); José Dias do Nascimento Jr. (7)

(1) Dep. de Física Teórica e Experimental, Universidade Federal do Rio Grande do Norte, Natal, Brazil; (2) Dep. de Física, Universidade Federal de Minas Gerais, Brazil; (3) Institut d'Astrophysique Spatiale, Université Paris XI,France

One of the most enigmatic phenomena related to solar activity is the so-called Maunder minimum phase. It consists of the lowest sunspot's counting ever registered for the Sun, and never so far confirmed for other stars. Since the spectroscopic observations of stellar activity at the Mount Wilson Observatory, the solar analog HD43587 has shown a very low and apparently invariant activity level, which makes it a Maunder minimum candidate. We analyze the chromospheric activity evolution of HD43587 and its evolutive status, intending to unravel the reasons for this low and flat activity. We use an activity measurements dataset available in the literature, and compute the activity S-index from HARPS and NARVAL spectra, to infer a cycle period. Besides, we analyze the CoRoT light-curve of HD43587, and apply gyrochronology and activity calibrations, to determine its rotation period. Finally, based on an evolutionary model and the inferred rotation period, we use the EULAG-MHD code to perform global MHD simulations of HD43587 with the aim of getting some insights about its dynamo process. We confirm the almost flat activity profile, with a cycle period $P_{\rm cyc} = 10.44 \pm 3.03$ yrs deduced from the S-index time series, and a longer period larger than 50 yrs. It was impossible to define a rotation period from the light-curve, however, gyrochronology and activity calibrations allow us to infer an indirect estimate of $\overline{P}_{\rm rot} = 22.62 \pm 2.94$ d. Furthermore, the MHD simulations confirm an oscillatory dynamo with a cycle period in good agreement with the observations and a low level of surface magnetic activity. We conclude that this object might be experiencing a "natural" decrease in magnetic activity as a consequence of its age. Nevertheless, the possibility that HD43587 is in a Maunder minimum phase cannot be ruled out.

A polarimetric direct detection of a circumplanetary disk around CT Cha b

Tobias O. B. Schmidt for the SPHERE consortium

Hamburger Sternwarte, University of Hamburg, Germany

Within the SHINE survey and the disk part of the Sphere consortium survey on the SPHERE high-contrast imager at VLT we followed up on a very young star with sub-stellar companion. We can

clearly show the companion to be co-moving, having a mass close to the deuterium burning limit, but likely below, from atmospheric model fitting and additionally exhibiting strong accretion signatures, easily visible by strong Hα flux emission with respect to the remaining spectrum. We recently performed polarimetric follow-up and besides the detection of a disk around the primary star, we could identify the degree and angle of linear polarization of the companion to differ strongly from the primary star's and from the expected polarization of an unrelated not co-moving background object within the FoV. Emission, pointing thus likely to accretion, in Hα and Pa β in combination with the polarization of about 1 % are well consistent with a circumplanetary disk at only slightly more than 1 Myr of age.

The bipolar molecular outflow of the very low-mass star Par-Lup3-4

Itziar de Gregorio-Monsalvo (1); Nuria Huélamo (2); Adele Plunkett (3); Álvaro Ribas (4); Fernando Comerón (5); Matthias Rudolph Schreiber (6); Cristian López (7); Koraljka. Mužic (8); L. Testi (9)

(1) European Southern Observatory; (2) Centro de Astrobiología (INTA-CSIC); (3) National Radio Astronomy Observatory; (4) European Southern Observatory; (5) European Southern Observatory; (6) Universidad de Valparaíso; (7) Joint ALMA Observatory; (8) CENTRA; (9) European Southern Observatory & INAF

Very low-mass stars are known to have jets and outflows, indicative of a scaled-down version of low-mass star formation. However, the number of well characterized outflows in very low-mass sources is still very low. We characterize the bipolar molecular outflow of the very low-mass star Par-Lup3-4, a 0.12 $M_{\odot}$ object known to power an optical jet. The source was observed with ALMA in Bands 6 and 7, detecting both the continuum and CO molecular gas. In particular, we studied three main emission lines: CO(2-1), CO(3-2), and ^{13}CO(3-2). Our observations reveal, for the first time, the base of a bipolar molecular outflow in a very low-mass star, as well as a secondary structure moving perpendicular to the primary outflow of this source. The primary outflow morphology is consistent with the previously determined jet orientation and disk inclination. The outflow mass is $9.5\times10^{-7}M_{\odot}$ with an outflow rate of $4.3\times10^{-9}M_{\odot}$/yr. A new fitting to the SED suggests that Par-Lup3-4 may be a binary system. We have characterized Par-Lup3-4 in detail, and its properties are consistent with those reported in other very low-mass sources. This source provides further evidence for very low-mass sources forming as a scaled-down version of low-mass stars.

The NGTS clusters survey: understanding the early evolution of stellar and planetary systems

Edward Gillen (1); Simon Hodgkin (2); Didier Queloz (3); Joshua Briegal (4); Gareth Smith (5); James Jackman (6); Peter Wheatley (7); Louise Nielsen (8); Matt Burleigh (9); Chris Watson (10); Phillip Eigmuller (11); Jose Vines (12); and the NGTS consortium (13)

(1) University of Cambridge; (2) University of Cambridge; (3) University of Cambridge; (4) University of Cambridge; (5) University of Cambridge; (6) University of Warwick; (7) University of Warwick; (8) Universite de Geneve; (9) University of Leicester; (10) Queen's University Belfast; (11) DLR Berlin; (12) Universidad de Chile

Young open clusters are fruitful astrophysical laboratories because their members share broad co-evality, composition and location. Combining information from different open clusters, which span a range of ages, offers a powerful probe of both stellar and planetary system evolution. The Next

Generation Transit Survey (NGTS) is a wide-field photometric facility comprised of 12 independent robotic telescopes based at ESO's Paranal Observatory. NGTS is conducting a systematic survey of nearby young open clusters with ages between 1 Myr – 2 Gyr, which are each being continually monitored over ∼200+ nights. I will introduce the NGTS clusters survey, and present recently published and new results from our first clusters, which include Blanco 1 (∼115 Myr) and the Orion star forming region (1-10 Myr). These results provide new insights into the early evolution of stellar rotation, flare frequency and the star-disk interaction, as well as precise constraints on fundamental stellar parameters from new eclipsing binary systems. Finally, I will conclude with an outlook towards future prospects for the survey and our understanding of young stellar systems.

Simultaneous Multi-wavelength Observation of Flares on a Flaring M dwarf: EV Lacertae

Rishi R. Paudel (1); Thomas Barclay (2); Joshua E. Schlieder (3); Emily A. Gilbert (4); Laura D. Vega (5); Allison Youngblood (6); Teresa A. Monsue (7); Michele L. Silverstein (8); Elisa V. Quintana (9); Kenji Hamaguchi (10); Knicole D. Colon (11); Daniel Huber (12)

(1) NASA Goddard Space Flight Center & University of Maryland, Baltimore County; (2) NASA Goddard Space Flight Center & University of Maryland, Baltimore County; (3) NASA Goddard Space Flight Center; (4) University of Chicago & NASA Goddard Space Flight Center; (5) NASA Goddard Space Flight Center & Vanderbilt University; (6) Laboratory for Atmospheric and Space Physics; (7) NASA Goddard Space Flight Center; (8) NASA Goddard Space Flight Center & RECONS Institute; (9) NASA Goddard Space Flight Center; (10) NASA Goddard Space Flight Center & University of Maryland, Baltimore County; (11) NASA Goddard Space Flight Center; (12) University of Hawaii

During a flare, energy is released by a star at wavelengths spanning all the way from X-rays to radio. By studying flares with multi-wavelength datasets we can understand correlation between energies in various wavelengths and hence estimate the total energy output during flares. We acquired data of nearby dM3.5e star EV Lac using 5 different observatories: NASA's $TESS$ mission, NASA's Neil Gehrels Swift Observatory ($Swift$), NASA's Neutron Interior Composition Explorer ($NICER$) and two ground based telescopes (University of Hawaii 2.2-m (UH88) and Las Cumbres Observatory Global Telescope (LCOGT) Network), to span a comprehensive, simultaneous wavelength coverage of flaring events. During the 27 days of continuous $TESS$ Cycle 2 observations, we acquired 3 simultaneous ∼11 ks UV/X-ray observations using $Swift$, 21 simultaneous ∼100 ks X-ray observations using $NICER$, 1 with UH88, and 1 with LCOGT. This provides an unprecedented number of overlapping measurements/wavelength coverage. We identified 32 flares in the $TESS$ light curve, 8 flares in the $Swift\ UVM2$ light curve and 13 flares in the $NICER$ light curve. However, we did not identify any flares in the $Swift$ XRT light curve or UH88 spectrum. One of the flares was observed simultaneously by $Swift$ UVOT and $TESS$ mission, and 8 flares were observed simultaneously by $NICER$ and $TESS$. We compare the energies of flares observed simultaneously by different missions. We also analyze white light flare frequency distribution of EV Lac using $TESS$ data. Our results will be helpful in estimating the white light flare rates as well as total energy emitted during flares of different amplitudes and durations from stars with spectral type and age comparable to EV Lac.

Modeling Solar Wind variation over an 11-yr cycle with Alfven Wave Dissipation: a parameter study

Soumitra Hazra; Victor Reville; Barbara Perrie; Antoine Strugarek; Allan Sacha Brun; Eric

Buchlin

Université Paris-Saclay, CNRS, CEA, Astrophysique, Instrumentation et Modélisation de Paris-Saclay, 91191, Gif-sur-Yvette, France

The stellar wind is generally believed as a mechanism responsible for the spin down of main-sequence stars. Many studies have been performed on the extraction of angular momentum by stellar winds. However, most of the previous studies generally consider simple dipole or quadrupolar magnetic topologies. In this work, we consider realistic magnetic topologies of the Sun, observed at the Wilcox Solar Observatory. We perform solar wind simulations with Alfven wave dissipation at different phases of the solar cycle with a 2.5D spherical, axisymmetric solar wind model, with realistic magnetic topology as a bottom boundary condition. We are able to reproduce general solar wind structure and recover the solar-like values of mass loss rate and angular momentum loss. Finally, we compare polytropic solution to solutions including a more realistic heating source term based on Alfven wave turbulence.

New Constraints on the Initial Mass Function and Birth History of Brown Dwarfs in the Solar Neighborhood from a Volume-Limited Sample

William M. J. Best (1); Michael C. Liu (2); Eugene A. Magnier (3); Trent J. Dupuy (4); Aniket Sanghi (5)

(1) University of Texas at Austin; (2) Institute for Astronomy, University of Hawaii; (3) Institute for Astronomy, University of Hawaii; (4) Gemini Observatory; (5) University of Texas at Austin

As the extreme lowest-mass products of star formation, brown dwarfs are essential to understanding the star formation history of our galaxy. To this end, a complete volume-limited sample of brown dwarfs in the solar neighborhood is critical for testing formation theories. To create such a sample, we have measured parallaxes for 348 L and T dwarfs using the wide-field infrared camera WFCAM on UKIRT to reach well beyond the limits of Gaia, producing the largest single batch of parallaxes for brown dwarfs to date and complementing other recent parallax programs targeting young or very late-type brown dwarfs. We constructed a volume-limited sample of brown dwarfs out to 25 pc covering two-thirds of the sky, the largest such sample ever created for brown dwarfs. Our volume-limited sample presents a comprehensive portrait of the local substellar population, including a precise estimate of the space density and an updated luminosity function. We use population synthesis and substellar evolutionary models to determine new estimates for the initial mass function and birth history of substellar objects in the Solar neighborhood.

Modeling Solar Wind variation over an 11-yr cycle with Alfven Wave Dissipation: a parameter study

Soumitra Hazra (1); Victor Reville (2); Barbara Perrie (3); Antoine Strugarek (4); Allan Sacha Brun (5); Eric Buchlin (6)

(1) Université Paris-Saclay, CNRS, CEA, Astrophysique, Instrumentation et Modélisation de Paris-Saclay, 91191, Gif-sur-Yvette, France; (2) Université Paris-Saclay, CNRS, Institut d'astrophysique spatiale, 91405, Orsay, France; (3)

The stellar wind is generally believed as a mechanism responsible for the spin down of main-sequence stars. Many studies have been performed on the extraction of angular momentum by

stellar winds. However, most of the previous studies generally consider simple dipole or quadrupolar magnetic topologies. In this work, we consider realistic magnetic topologies of the Sun, observed at the Wilcox Solar Observatory. We perform solar wind simulations with Alfven wave dissipation at different phases of the solar cycle with a 2.5D spherical, axisymmetric solar wind model, with realistic magnetic topology as a bottom boundary condition. We are able to reproduce general solar wind structure and recover the solar-like values of mass loss rate and angular momentum loss. Finally, we compare polytropic solution to solutions including a more realistic heating source term based on Alfven wave turbulence.

How should we characterize stellar photometric amplitudes?

Derek Buzasi (1); Hannah Andrews (2); Lindsey Carboneau (3)

(1) Florida Gulf Coast University; (2) Florida Gulf Coast University; (3) University of Birmingham

The CoRoT, Kepler, and TESS missions have given us an unprecedented number of high-precision stellar light curves displaying rotational modulation, and from these light curves we generally derive rotation periods and photometric amplitudes. While the literature is replete with explorations of the strengths and weaknesses of a number of techniques for period determination, the same cannot be said for measurements of photometric amplitude, a parameter which is intrinsically poorly defined both because rotational variability isn't strictly periodic and because the envelope of variability is itself variable as a function of time. Broadly speaking, popular characterizations of photometric amplitude rely on either a measure of the range of stellar flux values (such as that between the 5th and 95th percentiles), application of a sliding temporal window with width related to the stellar rotation period (such as the photometric S-index), or an evaluation of the phase-folded and smoothed stellar light curve.

Here we examine the utility of each of these approaches as applied to a sample of approximately 1000 variables with known rotation periods selected from the original Kepler sample. We resample the Kepler light curves numerous times using the TESS observing windows in order to simulate the shorter observing periods of the latter mission while retaining a level of "ground truth." We find that each approach suffers from both imprecision, which is a significant contributing factor to the scatter in observed rotation-activity-age relations, and bias, which is important for interpreting TESS light curves and which is currently unrecognized.

The Scorpius-Centaurus association and its kinematic ages with Chronostar

Marusa Zerjal (1); Michael Ireland (2); Aaron Rizzuto (3); Tim Crundall (4)

(1) Australian National University; (2) Australian National University; (3) The University of Texas at Austin; (4) University of Cologne

Chronostar is a novel kinematic analysis tool to search for overdensities in the full 6D kinematic phase-space. It is able to overcome the circular dependency between the list of members of an association and its fitted model by using the Expectation-Maximisation algorithm. This introduces a potential to discover unknown overdensities present in the data as well as a detailed characterization of both their dense and more diffuse subcomponents. Its performance is significantly improved by the orbital trace-forward approach that propagates a model from the birth site to the present-day position and thus minimizes the effect of observational errors. This enables a reliable kinematic age estimation as a time required for the model to move from the birth site to the current position.

The inclusion of age priors from our catalogue of new spectroscopically identified young stars in the Solar neighbourhood (3500 of them have lithium 6708 line) yields a detailed characterization of the complex moving groups. I will present the analysis of the Scorpius-Centaurus OB2 association that finds 10,000 members in numerous subcomponents of different kinematic ages.

How hot can flares from cool stars be?

Hans Moritz Günther

MIT

The most energetic events on cool stars are coronal flares. There is initial evidence that flares on pre-main sequence stars differ from their main-sequence counterparts. As the hard X-rays generated in rare, but energetic flares can penetrate deep into the circumstellar disk, they strongly influence the disk chemistry with decisive consequences for star formation. Thus, we need an accurate and complete census of flare rates and flare energies from young stars. We ppresent 90 ks of simultaneous Chandra and NuStar observations of the Orion Nebular Cloud (ONC). NuStar allows us to directly measure the high energy tail of the flare distribution above 10 keV, while Chandra will resolve the sources in the dense core of the ONC to pin-point the origin of the flares.

Defining Benchmark M-Dwarf Age Properties from Gaia DR2 Clusters

Ellianna Abrahams (1); Courtney D. Dressing (2); Andrew W. Mann (3); Ruth Angus. (4)

(1) UC Berkeley; (2) UC Berkeley; (3) UNC Chapel Hill; (4) American Museum of Natural History

M dwarfs have much longer main sequence lifetimes than the Sun and provide stable habitable zones for hundreds of billions of years, perhaps making M dwarf planets some of the most habitable in the galaxy. However, these long lifetimes make it hard to easily distinguish the age of an M dwarf from direct observables. We explore the relationship between M dwarf ages and observables as they relate to fundamental stellar characteristics like L_{bol}, T_{eff}, M_* and R_* for a sample of >10,000 low-mass stars. Using confirmed stellar cluster members from Gaia DR2, with ages ranging from 115 Myr - 1 Gyr, we define a sample of M dwarf candidates from the extinction-corrected Color-Magnitude Diagram (CMD). We calculate the spectral energy distributions (SEDs) of these objects, using distances from Gaia and available archival photometry (e.g., AllWISE, 2MASS, SDSS, and PANSTARRS). We fit the SEDs for a direct measure of L_{bol}, and infer T_{eff}, M_* and R_* using empirically based measurements for these stars, rejecting those that do not qualify as M dwarfs according to their stellar parameters. We explore which observables and parameters provide the most directly informative measure of age for these cool stars, which will allow us to define probabilistic M dwarf isochrones in parameter space. These results will be used to infer the ages of M dwarfs beyond clusters, including exoplanetary hosts, helping to constrain the possible evolutionary stages of any orbiting exoplanets.

K. Isaak

ESA CHEOPS Project Team and the Mission Consortium

European Space Agency/ESTEC

Launched in December 2019, CHEOPS (CHaracterising ExOPlanet Satellite) is the first exoplanet mission dedicated to the search for transits of exoplanets by means of ultrahigh precision photometry of bright stars already known to host planets. It is a partnership between Switzerland and ESA, with important contributions from 10 other member states, and will provide the unique capability of determining accurate radii for a subset of those planets in the super- Earth to Neptune mass range, for which the mass has already been estimated from ground- based spectroscopic surveys. It will also provide precision radii for new planets discovered by the next generation of ground- and space-based transit surveys. By combining known masses with CHEOPS sizes, it will be possible to determine accurate densities of sub-saturn size planets, providing key insight into their composition and internal structure. By identifying transiting exoplanets with high potential for in-depth characterisation – for example, those that are potentially rocky and have thin atmospheres - CHEOPS will also provide prime targets for future instruments suited to the spectroscopic characterisation of exoplanetary atmospheres.

The high photometric precision of CHEOPS will be achieved using a photometer covering the 0.35 - 1.1um waveband, designed around a single frame transfer CCD which is mounted in the focal plane of a 30 cm equivalent aperture diameter, f/5 on-axis Ritchey-Chretien telescope. CHEOPS will reach a photometric precision of 20 parts per million in a 6 hour observation of a v-band magnitude 9, G-type (Teff =5500K) dwarf, commensurate with measuring the transit depth of an Earth-size planet transiting the same star to a signal-to-noise of 5. In the case of fainter stars, CHEOPS will reach a photometric precision of 85 parts per million in a 3 hour observation of a v-band magnitude 12, K-type (Teff =4500K) dwarf.

80 per cent of the observing time in the 3.5 year nominal mission lifetime will be taken by the Guaranteed Time Programme, defined by the CHEOPS Science Team. The remaining 20 per cent will be available to guest observers from the Community through a competitive proposal submission process, comprising annual Calls and a discretionary time component.

In this talk I give an overview of the mission and the opportunities it offers to the stellar community.

The EvryFlare survey: habitability impacts and flare color evolution for a large sample of superflares observed simultaneously by Evryscope and TESS

Ward S. Howard (1); Nicholas M. Law (2); Jeffrey K. Ratzloff (3); Hank Corbett (4); Amy Glazier (5); Nathan Galliher (6); Ramses Gonzalez (7); Alan Vasquez Soto (8); Octavi Fors (9); Daniel del Ser (10); Joshua Haislip (11)

(1) Department of Physics and Astronomy, University of North Carolina at Chapel Hill; (2) Department of Physics and Astronomy, University of North Carolina at Chapel Hill; (3) Department of Physics and Astronomy, University of North Carolina at Chapel Hill; (4) Department of Physics and Astronomy, University of North Carolina at Chapel Hill; (5) Department of Physics and Astronomy, University of North Carolina at Chapel Hill; (6) Department of Physics and Astronomy, University of North Carolina at Chapel Hill; (7) Department of Physics and Astronomy, University of North Carolina at Chapel Hill; (8) Department of Physics and Astronomy, University of North Carolina at Chapel Hill; (9) Dept. de Física Quàntica i Astrofísica, Institut de Ciències del Cosmos (ICCUB), Universitat de Barcelona; (10) Dept. de Física Quàntica i Astrofísica, Institut de Ciències del Cosmos (ICCUB), Universitat de Barcelona; (11) Department of Physics and Astronomy, University of North Carolina at Chapel Hill

Does the temperature evolution of stellar flares determine the habitability of Earth-like planets? The combined line and continuum flare emission is usually approximated by a 9000 K blackbody. The blackbody temperature is a key ingredient in modeling the effects of superflares upon the atmo-

spheric photochemistry of Earth-like planets, governing the fraction of the stellar flare energy emitted at UV wavelengths. We observe hundreds of AD Leo type superflares from a diverse sample of K5-M5 stars with the Evryscope all sky array of small telescopes, including superflares from Proxima Cen and the LTT 1445 system. We measure flare blackbody temperatures using the color-evolution of dozens of superflares that have simultaneous 2 min cadence observations from both Evryscope and TESS. We test the assumption of a 9000 K blackbody against our superflares: preliminary results indicate some events reach in excess of 15-30,000 K. Planetary atmospheres and surface life may therefore potentially be exposed to a tenfold increase in UV radiation during large optical flares. We find the impulsiveness of optical flares and their blackbody temperature is well-described by a power law, allowing estimates of a given flare's temperature from the optical. We observe 14.6$\pm$2% of the stars around which TESS may discover temperate rocky planets emit flares large enough to significantly affect the potential habitability of those planets. We will discuss observations of a superflare with sufficient energy to photo-dissociate all ozone in an Earth-like atmosphere in a single event. We observe a decrease in superflare rates and energies at longer stellar rotation periods, observing a possible change in the superflare rates of M-dwarfs in the period gap reported in previous studies.

Using Deep Learning to Characterize Stellar Rotation from Light Curves

Jennifer van Saders

Institute for Astronomy, University of Hawai'i

Stellar rotation is fundamentally linked to the structure, evolution, and magnetic activity of stars. Conventional techniques to measure rotation from light curves 1) are not particularly suited to inferring differential rotation, spot latitudes, or lifetimes, 2) are subject to aliases that cause factor-of-two errors in the period estimate, and 3) have little innate ability to separate systematics from signal. Deep Learning techniques can be trained to recognize a richer set of light curve features and thus may be more sensitive. They are also fast, once trained. Without having a large number of examples where the rotation characteristics are already known, simulations are our best hope at generating training sets. I will present `butterpy`, a Python package that simulates star spot emergence and evolution, similar to a Solar butterfly diagram, and computes rotational light curves. Using `butterpy` to generate large training sets, we have used Deep Neural Networks to estimate rotation periods and other properties of interest from light curves. I will present the full set of light curves, which will be made publicly available, and discuss how reliably we can recover rotational properties. Finally, I will discuss what we hope to glean from over 400,000 light curves from the TESS Continuous Viewing Zones.

Physical properties of the nearby population across the hydrogen-burning limit

Daniella C. Bardalez Gagliuffi (1); Adam J. Burgasser (2); Sarah J. Schmidt (3); Christopher Theissen (4); Jonathan Gagné (5); Michael Gillon (6); Johannes Sahlmann (7); Jacqueline K. Faherty (8); Christopher Gelino (9); Kelle L. Cruz (10); Nathalie Skrzypek (11); Dagny Looper (12)

(1) American Museum of Natural History; (2) University of California, San Diego; (3) Leibniz-Institute for Astrophysics Potsdam (AIP); (4) Université de Montréal; (5) Université de Liège; (6) Space Telescope Science Institute (STScI); (7) Infrared Processing and Analysis Center

(IPAC); (8) NASA Exoplanet Science Institute (NExSci), California Institute of Technology; (9) Hunter College, City University of New York; (10) Graduate Center, City University of New York; (11) Center for Computational Astrophysics, Flatiron Institute; (12) Imperial College; (13) CBS Studios

The solar neighborhood is the best studied stellar sample due to its proximity to Earth, and its thorough characterization is key to extrapolate to more distant, sparser samples. Aided by the advent of Gaia and low-resolution near-infrared spectroscopy from SpeX, we have carefully characterized the nearby 25pc volume of ultracool dwarfs encompassing the hydrogen-burning limit. In this talk, I will present population statistics of ultracool dwarfs straddling the hydrogen-burning limit in terms of color, youth and surface gravity, and multiplicity fraction, highlighting a severe incompleteness in the literature sample. Here I present your ultracool neighborhood!

Multi-Epoch, High-Resolution Radial Velocities of the Volume-Complete Sample of 412 Mid-to-Late M Dwarfs Within 15 pc

Jonathan Irwin; David Charbonneau; Amber Medina; Emily Pass; David Latham

Center for Astrophysics | Harvard & Smithsonian

Within 15 pc, there are 412 stars with masses 0.1 - 0.3 times the solar value. This sample represents a opportunity to study fully convective stars, the only viable targets for the study of terrestrial exoplanet atmospheres in the near future. Yet, our knowledge of this population is woefully incomplete: thirty percent have no published spectrum, while forty percent have only low-resolution spectroscopic measurements available from the literature.

We are nearing completion of our multi-epoch, high-resolution spectroscopic survey of these mid-to-late M dwarfs that lie within 15 pc. For targets north of DEC = -15 deg, we are using the Tillinghast Reflector Echelle Spectrograph (TRES, R = 44,000) on the 1.5m telescope at the Fred Lawrence Whipple Observatory (FLWO) on Mt. Hopkins, AZ. For targets south of DEC = -15 deg, we are using the CTIO HIgh ResolutiON (CHIRON, R = 80,000) spectrograph at the Cerro Tololo Inter-American Observatory / Small and Moderate Aperture Research Telescope System (CTIO / SMARTS) 1.5m telescope. We present here our measured systemic radial velocities and derived 3-D space motions. We also present our rotational velocities, and illustrate that roughly 20% rotate more rapidly than 10 km/s and that roughly 20% of the primary stars host stellar companions. We are also are determining the Jovian-mass companion occurence rate for these stars and are targeting them with TESS to determine their flare rates. Our survey has more than tripled the number of these stars with complete high-resolution spectroscopic, photometric, and trigonometric characterization.

This work is supported by grants from the John Templeton Foundation, the National Science Foundation, and NASA.

Achieving High Contrast with Reference Star Differential Imaging using Star Hopping on SPHERE at 1.6 μm

J. H. Girard; A.-M. Lagrange; J. S. Jenkins; J. Milli; V. Christiaens

Universidad de Chile, Bucknell University, European Southern Observatory, Institut de Planétologie et d'Astrophysique de Grenoble, Université de Liège, Monash University

Direct imaging of exoplanets is a difficult endeavor due to the high contrast between the star and companion planets, along with the small angular separations. Besides hardware such as adaptive

optics and coronagraphy, we can use post-processing techniques such as differential imaging to subtract the star's light, with angular differential imaging (ADI) and reference differential imaging (RDI) among the most popular. Using a "starhopping" technique where we rapidly changed between the A and B components of 55 Eri with SPHERE, we observed a high-quality data set for both ADI and RDI with 80 minutes of observations and 41° of parallactic angle change. We tested the two methods along with princial component analysis (PCA)-including counterparts by injecting fake companions and measured their signal-to-noise ratios and contrast curves. We consistently found better results for RDI at short separations. We also tested the photometry and astrometry retrieved after injecting 5000 fake companions inside and outside 0.3 arcsec with PCA+ADI and PCA+RDI, for which we found PCA+RDI providing the best measurements, especially at the inner separations. ADI turned up fewer false positives than RDI did. We show RDI to be a promising method to complement the ADI method, particularly in cases where we prefer short snapshot observations, imaging with space instrumentation, and where we want to image as close to the star as possible. This will be especially useful for the search and characterization of very low-mass companions with future telescope systems.

Combining optical interferometry and Gaia uncertainness to reveal the physics of Asymptotic Giant Branch stars

Andrea Chiavassa (1); Mathias Schulteis (2); Bernd Freytag (3); K. Kravchenko (4); F. Millour (5); G. Schaefer (6); O. Creevey (7); MIRC-X team (8)

(1) Lagrange/Observatoire de la Côte d'Azur; (2) Lagrange/Observatoire de la Côte d'Azur; (3) Uppsala University; (4) ESO-Chile; (5) Lagrange/Observatoire de la Côte d'Azur; (6) CHARA Array; (7) Lagrange/Observatoire de la Côte d'Azur

Low to intermediate mass stars evolve into the asymptotic branch of giants (AGB), increasing the loss of mass during this evolution by contributing significantly to the enrichment of the Galaxy. Their visible surface is made up of shock waves that are produced inside them and are shaped from the top of the convection zone as they travel outwards. Their complex stellar surface dynamics amplifies the uncertainties on stellar parameters and distances.

In the presence of luminosity asymmetries, the position of the intensity-weighted mean of all emitting points tiling the visible stellar surface (ie, photocentre) does not coincide with the barycentre of the star and changes as the convective pattern evolves over time. First, we calculated the displacement of the photocentre in the 3D radiation hydrodynamic (RHD) simulations of stellar convection computed with CO5BOLD code, and found that the convection-related surface structure show displacements up to about 11% of the stellar radius, accounting for a substantial part of the Gaia DR2 parallax error (Chiavassa et al. 2018, A&A, 617, L1). Furthermore, we performed interferometric observations with MIRC-X@CHARA to detect the presence of stellar surface inhomogenities. The comparison with 3D RHD simulations returns a very good agreement with the observations both in terms of contrast and surface structure morphology. Thanks to the high angular resolution, it is possible to quantify the complex morphology of AGB stars as not centrosymmetric and likely affecting astrometric Gaia measurements. This definitively confirms the presence of convection-related surface structures on the same Gaia DR2 object for which we proved the photocentre displacement (Chiavassa et al. 2020, submitted).

Combining our unique global 3D RHD simulations with Gaia data will allow to measure fundamental properties of AGB stars directly from Gaia errors, and, make it possible to systematically study the properties of convection in stars other than the Sun.

Magnetic topology of the pre-cataclysmic variable V471 Tau

Bonnie Zaire; Jean-François Donati; Baptiste Klein

CNRS/Université de Toulouse

We analyze spectropolarimetric data of the pre-cataclysmic variable V471 Tau binary system obtained with the ESPaDOnS instrument in two observational campaigns. We report surface spot maps and magnetic field tomographies of the K dwarf companion reconstructed with the Zeeman-Doppler imaging technique. We detect significant fluctuations in the surface shear. In one year interval, it goes from 1.7 times the solar differential rotation rate to the solar value (d$\Omega = 65$ mrad/d). We conclude that differential rotation fluctuations obtained for the K dwarf resemble the ones obtained for the analog star AB Dor. We reinforce previous findings of periodicity in the Hα line. While in the primary eclipse it is in absorption, it goes in emission when the secondary is being eclipsed. We also report the presence of hot plasma in emission at a distance of 2.2R from the rotation axis of the K dwarf and we discuss the possible Applegate effect operating within the K dwarf.

Does the ratio of coronal to chromospheric heating change to cooler stars?

Jeffrey L. Linsky (1); Brian Wood (2); Allison Youngblood (3); Alexander Brown (4); Peter Wheatley (5); the Mega-MUSCLES Team (6)

(1) JILA/University of Colorado; (2) US Naval Reasearch Lab.; (3) LASP/University of Colorado; (4) CASA/University of Colorado; (5) University of Warwick

We describe the steep decline of chromospheric emission relative to coronal emission between solar-type and M-dwarf stars. The coronal emission is measured by the X-ray flux obtained with XMM-Newton and Chandra, and the chromospheric emission is measured by the reconstructed Lyman-alpha flux obtained with the HST including the MUSCLES and Mega-MUSCLES stars. As stars age on the main sequence with decreasing rotation and magnetic activity, they follow a linear trajectory in the log (X-ray) vs log (Lyman-alpha) diagram. G and K stars follow the same trajectory, but M stars increasing deviate from this trajectory with decreasing effective temperature. This result indicates that the relative heating of coronae vs chromospheres is very different in the coolest stars.

The Directly-Measured Intrinsic Lyman-α Profiles of G, K, and M dwarfs

Allison Youngblood (1); Brian Wood (2); Kevin France (3); Jeffrey Linsky (4); Seth Redfield (5); Thomas Ayres (6)

(1) University of Colorado Boulder; (2) Naval Research Laboratory; (3) University of Colorado Boulder; (4) University of Colorado Boulder; (5) Wesleyan University; (6) University of Colorado Boulder

H I Lyman-α (1216 Å) is the brightest emission line in the UV spectrum of F, G, K, and M dwarfs and plays a critical role in energy transport in the stellar chromosphere, probing the density structure of the ISM, and chemistry of exoplanet atmospheres. Accurately characterizing this emission line is important, however, interstellar H I gas removes more than 50% of the stellar Lyman-α flux even for the nearest stars, necessitating reconstruction from the observed line profile wings and an assumed shape for the line core. The Sun exhibits line core self-reversal, and evidence from other

chromospheric emission lines like Mg II (2796, 2802 Å) shows that self-reversal depth varies with stellar mass and possibly activity. We have directly measured the Lyman-α line core shapes for five high radial velocity stars (G8 V to M4 V), whose fast motion along the line-of-sight Doppler shifts the Lyman-α peak out of the interstellar absorption trough. We quantify the self-reversal depth, width, and symmetry, compare amongst spectral types and activity levels, compare to Mg II and Ca II self-reversal, and quantify the effect of ignoring self-reversal on the accuracy of Lyman-α reconstructions.

Amplification of photometric variability by active-region nesting in solar-like stars

Emre Isik (1); Alexander I. Shapiro (2); Sami K. Solanki (3); Natalie A. Krivova (4)

(1) Turkish-German University; (2) Max Planck Institute for Solar System Research; (3) Max Planck Institute for Solar System Research; (4) Max Planck Institute for Solar System Research

Solar-type stars with near-solar rotation periods observed with *Kepler* exhibit a large variability scatter in rotational timescales, with light curve amplitudes of up to 6 times that of the Sun. We synthesise 4.4-year Kepler-band light curves of solar-like stars, by considering active regions (ARs) in the form of spots and faculae with Sun-like characteristics. We carry out these numerical experiments at a range of activity levels, corresponding to an S-index range of 0.16 to 0.30. The novel feature of the model is that ARs emerge at sites of recent AR emergence by given probabilities, similar to AR nesting observed on the Sun. We set up different modes and strengths of nesting, and take surface differential rotation into account. We find that the combined effect of the degree of nesting and the activity level, both being somewhat higher than on the Sun, can explain the whole range of observed light-curve amplitudes of solar-like stars.

Detectability of solar gravity modes generated by penetrative convection

Charly Pinçon (1); Kévin Belkacem (2); Marc-Antoine Dupret (3)

(1) FNRS/Université de Liège/Observatoire de Paris; (2) Observatoire de Paris; (3) Université de Liège

The detection of gravity oscillation modes is expected to provide us invaluable information on the properties of solar core where they can propagate. In turn, owing to their evanescent behavior in the convective envelope, their amplitudes remain very small at the surface. More than twenty years ago, the GOLF instrument on board of the SoHO spacecraft aimed to measure the small variations induced by these oscillations in the solar full-disk radial velocity. Nevertheless, despite numerous efforts, there is currently no consensus on the detection of gravity modes in the Sun. Within this framework, theoretical predictions of their amplitudes are essential to guide observations and design future instruments. Previous studies considered the turbulent Reynold's stress in the convective zone as the driving process. The authors concluded that the current detection threshold is still too high to enable us to observe gravity modes in the Sun. However, this result does not account for the excitation mechanism by penetrative convection. The penetration of downward turbulent plumes at the top of the radiative zone is known to emit efficiently low-frequency progressive waves into the solar core. Its influence on the gravity modes amplitudes is thus expected to be important. In this talk, we will present a semianalytical excitation model of gravity modes that we developed by considering penetrative convection as the driving process. The model predictions will be compared to previous

works and the detection threshold. The seismic potential of gravity modes to bring us constraints on penetrative convection at the base of the convective envelope will be also emphasized.

A Transiting Planet Discovered around a Nearby Pre-Main Sequence Star

Peter Plavchan (1); Thomas Barclay (2); Jonathan Gagné (3); Peter Gao (4); Bryson Cale (5); William Matzko (6); Diana Dragomir (7); Sam Quinn (8); Dax Feliz (9); Keivan Stassun (10); Ian J.M. Crossfield (11); David A. Berardo (12); David W Latham (13); Ben Tieu (14); Guillem Anglada-Escudé (15); George Ricker (16); Roland Vanderspek (17); Sara Seager (18); Joshua N. Winn (19); Jon M. Jenkins (20); Stephen Rinehart (21); Akshata Krishnamurthy (22); Scott Dynes (23); John Doty (24); Fred Adams (25); Dennis A Afanasev (26); Chas Beichman (27); Mike Bottom (28); Brendan P. Bowler (29); Carolyn Brinkworth (30); Carolyn J. Brown (31); Andrew Cancino (32); David R. Ciardi (33); Mark Clampin (34); Jake T. Clark (35); Karen Collins (36); Cassy Davison (37); Daniel Foreman-Mackey (38); Elise Furlan (39); Eric Gaidos (40); Claire Geneser (41); Frank Giddens (42); Emily Gilbert (43); Ryan Hall (44); Coel Hellier (45); Todd Henry (46); Jonathan Horner (47); Andrew W. Howard (48); Chelsea Huang (49); Joseph Huber (50); Stephen R Kane (51); Matthew Kenworthy (52); John Kielkopf (53); David Kipping (54); Chris Klenke (55); Ethan Kruse (56); Natasha Latouf (57); Patrick Lowrance (58); Bertrand Mennesson (59); Matthew Mengel (60); Sean M. Mills (61); Tim Morton (62); Norio Narita (63); Elisabeth Newton (64); America Nishimoto (65); Jack Okumura (66); Enric Palle (67); Joshua Pepper (68); Elisa V. Quintana (69); Aki Roberge (70); Veronica Roccatagliata (71); Joshua E. Schlieder (72); Angelle Tanner (73); Johanna Teske (74); C. G. Tinney (75); Andrew Vanderburg (76); Kaspar von Braun (77); Bernie Walp (78); Jason Wang (79); Sharon Xuesong Wang (80); Denise Weigand (81); Russel White (82); Robert A. Wittenmyer (83); Duncan J. Wright (84); Allison Youngblood (85); Hui Zhang (86); Perri Zilberman (87)

(1) Department of Physics and Astronomy, George Mason University, 4400 University Drive, MSN 3F3, Fairfax, VA 22030, USA; (2) University of Maryland, College Park, Department of Astronomy, College Park, MD, 20742; (3) Institute for Research on Exoplanets, Université de Montréal, Département de Physique, C.P. 6128 Succ. Centreville, Montréal, QC H3C 3J7, Canada; (4) University of California, Berkeley, Berkeley, CA 94720, USA, 51 Pegasi b Fellow; (5) Department of Physics and Astronomy, George Mason University, 4400 University Drive, MSN 3F3, Fairfax, VA 22030, USA; (6) Department of Physics and Astronomy, George Mason University, 4400 University Drive, MSN 3F3, Fairfax, VA 22030, USA; (7) Massachusetts Institute of Technology, 54-1718 77 Mass. Avenue, Cambridge, MA, USA; (8) Department of Physics and Astronomy, University of New Mexico, Albuquerque, NM, USA; (9) Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA; (10) Vanderbilt University, Department of Physics & Astronomy, 6301 Stevenson Center Lane, Nashville, TN 37235, USA; (11) Vanderbilt University, Department of Physics & Astronomy, 6301 Stevenson Center Lane, Nashville, TN 37235, USA; (12) Massachusetts Institute of Technology, 54-1718 77 Mass. Avenue, Cambridge, MA, USA, Department of Physics & Astronomy, University of Kansas, 1251 Wescoe Hall Dr, Lawrence, KS 66045, USA; (13) Massachusetts Institute of Technology, 54-1718 77 Mass. Avenue, Cambridge, MA, USA; (14) Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA; (15) Department of Physics and Astronomy, George Mason University, 4400 University Drive, MSN 3F3, Fairfax, VA 22030, USA; (16) School of Physics and Astronomy, Queen Mary, University of London, 327 Mile End Road, London, UK; (17) Massachusetts Institute of Technology, 54-1718 77 Mass. Avenue, Cambridge, MA, USA; (18) Massachusetts Institute of Technology, 54-1718 77 Mass. Avenue, Cambridge, MA, USA; (19) Massachusetts Institute of

Technology, 54-1718 77 Mass. Avenue, Cambridge, MA, USA; (20) Department of Astrophysical Sciences, Princeton University, 4 Ivy Lane, Princeton NJ 08544, USA; (21) SETI Institute, 189 N Bernardo Ave suite 200, Mountain View, CA 94043, USA; (22) NASA Goddard Space Flight Center, Exoplanets and Stellar Astrophysics Laboratory, 8800 Greenbelt Road, Greenbelt, MD, 20771, USA; (23) Massachusetts Institute of Technology, 54-1718 77 Mass. Avenue, Cambridge, MA, USA; (24) Massachusetts Institute of Technology, 54-1718 77 Mass. Avenue, Cambridge, MA, USA; (25) Noqsi Aerospace Ltd, 15 Blanchard Ave., Billerica, MA, 01821, USA; (26) Department of Astronomy, University of Michigan, 108 S. University, 323 West Hall, Ann Arbor, Michigan, 48109-1107, USA; (27) Department of Astrophysical Sciences, Princeton University, 4 Ivy Lane, Princeton NJ 08544, USA; (28) Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA 91109-8099, USA, NASA Exoplanet Science Institute, California Institute of Technology, M/C 100-22, 770 South Wilson Avenue, Pasadena, CA 91125, USA; (29) Institute for Astronomy, University of Hawaii at Manoa, 1680 East-West Road, Honolulu, HI 96822, USA; (30) The University of Texas at Austin, Astronomy 2515 Speedway, Stop C1400, Austin, TX 78712-1205, USA; (31) University Corporation for Atmospheric Research, 3090 Center Green Drive, Boulder CO 80301, USA; (32) University of Southern Queensland, Centre for Astrophysics, Toowoomba, Qld 4350, Australia; (33) Missouri State University, Department of Physics, Astronomy and Materials Science, 901 S National Ave., Springfield, MO 65897, USA; (34) NASA Exoplanet Science Institute, California Institute of Technology, M/C 100-22, 770 South Wilson Avenue, Pasadena, CA 91125, USA; (35) NASA Goddard Space Flight Center, Exoplanets and Stellar Astrophysics Laboratory, 8800 Greenbelt Road, Greenbelt, MD, 20771, USA; (36) University of Southern Queensland, Centre for Astrophysics, Toowoomba, Qld 4350, Australia; (37) Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA; (38) Department of Physics and Astronomy, Georgia State University, PO Box 4106, Atlanta, GA 30302-4106, USA; (39) Center for Computational Astrophysics, Flatiron Institute,162 5th Ave, New York, NY 10010, USA; (40) Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA 91109-8099, USA; (41) Department of Earth Sciences, University of Hawaii at Manoa, 1680 East-West Road, Honolulu, HI 96822, USA; (42) Mississippi State University, Department of Physics & Astronomy, Hilbun Hall, Starkville, MS, 39762, USA; (43) Missouri State University, Department of Physics, Astronomy and Materials Science, 901 S National Ave., Springfield, MO 65897, USA; (44) University of Chicago, The Department of Astronomy and Astrophysics, 5640 S. Ellis Avenue, Chicago, IL 60637, USA; (45) Department of Physics and Astronomy, Georgia State University, PO Box 4106, Atlanta, GA 30302-4106, USA; (46) Keele University, Staffordshire, UK, ST5 5BG; (47) RECONS Institute, Chambersburg, PA 17201, USA; (48) University of Southern Queensland, Centre for Astrophysics, Toowoomba, Qld 4350, Australia; (49) Department of Astronomy, California Institute of Technology, 1200 E California Blvd, Pasadena, CA 91125, USA; (50) Massachusetts Institute of Technology, 54-1718 77 Mass. Avenue, Cambridge, MA, USA; (51) Missouri State University, Department of Physics, Astronomy and Materials Science, 901 S National Ave., Springfield, MO 65897, USA; (52) Department of Earth and Planetary Sciences, University of California, Riverside, CA 92521, USA; (53) Leiden Observatory, Leiden University, P.O. Box 9513, 2300 RA Leiden, The Netherlands; (54) Department of Physics and Astronomy, University of Louisville, Louisville, KY 40292, USA; (55) Department of Astronomy, Columbia University, 550 W 120th Street, New York, NY 10027, USA; (56) Missouri State University, Department of Physics, Astronomy and Materials Science, 901 S National Ave., Springfield, MO 65897, USA; (57) NASA Goddard Space Flight Center, Exoplanets and Stellar Astrophysics Laboratory, 8800 Greenbelt Road, Greenbelt, MD, 20771, USA; (58) Department of Physics and Astronomy, George Mason University, 4400 University Drive, MSN 3F3, Fairfax, VA 22030, USA; (59) IPAC, California Institute of Technology, 1200 E California Blvd, Pasadena, 91125, USA; (60) Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA 91109-8099, USA; (61) University of Southern Queensland, Centre for Astrophysics, Toowoomba, Qld 4350, Australia; (62) Department of Astronomy, California Institute of Technology, 1200 E California Blvd, Pasadena, CA 91125, USA; (63)

Astronomy Department, University of Florida, 211 Bryant Space Science Center, P.O. Box 112055, Gainesville, FL 32611-2055, USA; (64) Department of Astronomy, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan, JST, PRESTO, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan, Astrobiology Center, NINS, 2-21-1 Osawa, Mitaka, Tokyo 181-8588, Japan, National Astronomical Observatory of Japan, NINS, 2-21-1 Osawa, Mitaka, Tokyo 181-8588, Japan, Instituto de Astrofisica de Canarias (IAC), 38205 La Laguna, Tenerife, Spain; (65) Department of Physics & Astronomy, Dartmouth College, Hanover, NH 03755, USA; (66) Missouri State University, Department of Physics, Astronomy and Materials Science, 901 S National Ave., Springfield, MO 65897, USA; (67) University of Southern Queensland, Centre for Astrophysics, Toowoomba, Qld 4350, Australia; (68) Instituto de Astrofisica de Canarias (IAC), 38205 La Laguna, Tenerife, Spain; (69) Department of Physics, Lehigh University, 16 Memorial Drive East, Bethlehem, PA 18015, USA; (70) NASA Goddard Space Flight Center, Exoplanets and Stellar Astrophysics Laboratory, 8800 Greenbelt Road, Greenbelt, MD, 20771, USA; (71) NASA Goddard Space Flight Center, Exoplanets and Stellar Astrophysics Laboratory, 8800 Greenbelt Road, Greenbelt, MD, 20771, USA; (72) Dipartimento di Fisica "Enrico Fermi", Universita' di Pisa, Largo Pontecorvo 3, 56127 Pisa, Italy, INAF-Osservatorio Astrofisico di Arcetri, Largo E. Fermi 5, 50125 Firenze, Italy, INFN, Sezione di Pisa, Largo Pontecorvo 3, 56127 Pisa, Italy; (73) NASA Goddard Space Flight Center, Exoplanets and Stellar Astrophysics Laboratory, 8800 Greenbelt Road, Greenbelt, MD, 20771, USA; (74) Mississippi State University, Department of Physics & Astronomy, Hilbun Hall, Starkville, MS, 39762, USA; (75) Observatories of the Carnegie Institution for Science, 813 Santa Barbara Street, Pasadena, CA 91101, USA; (76) Exoplanetary Science at UNSW, School of Physics, UNSW Sydney, NSW, 2052, Australia; (77) The University of Texas at Austin, Astronomy 2515 Speedway, Stop C1400, Austin, TX 78712-1205, USA, NASA Sagan Postdoctoral Fellow; (78) Lowell Observatory, 1400 W Mars Hill Road, Flagstaff, AZ 86001, USA; (79) NASA Infrared Telescope Facility, 640 North A'ohoku Place, Hilo, HI, 96720, USA; (80) The University of Texas at Austin, Astronomy 2515 Speedway, Stop C1400, Austin, TX 78712-1205, USA; (81) Department of Astronomy, California Institute of Technology, 1200 E California Blvd, Pasadena, CA 91125, USA, 51 Pegasi b Fellow; (82) Observatories of the Carnegie Institution for Science, 813 Santa Barbara Street, Pasadena, CA 91101, USA; (83) Missouri State University, Department of Physics, Astronomy and Materials Science, 901 S National Ave., Springfield, MO 65897, USA; (84) Department of Physics and Astronomy, Georgia State University, PO Box 4106, Atlanta, GA 30302-4106, USA; (85) University of Southern Queensland, Centre for Astrophysics, Toowoomba, Qld 4350, Australia; (86) University of Southern Queensland, Centre for Astrophysics, Toowoomba, Qld 4350, Australia; (87) NASA Goddard Space Flight Center, Exoplanets and Stellar Astrophysics Laboratory, 8800 Greenbelt Road, Greenbelt, MD, 20771, USA; (88) School of Astronomy and Space Science, Key Laboratory of Ministry of Education, Nanjing University, Nanjing, China; (89) SUNY Stony Brook, 100 Nicolls Road, Stony Brook, NY 11794; (90)

We report a planet orbiting a nearby pre-main sequence star with a debris disk, discovered using data from NASA's TESS mission and multi-wavelength radial velocities. The newly identified planet in this system can be used to investigate disk-planet interactions and inform the planet formation and migration process. We will present the near-infrared radial velocity technique we have developed using the iSHELL spectrometer on the NASA Infrared Telescope Facility. We will also discuss the effects of stellar activity and how multi-wavelength Doppler velocities may allow us to mitigate its effects in our search for planets with the Doppler technique.

Correcting Solar and Stellar Flare Distributions

Vinay L. Kashyap (1); Eun-jin Kim (2); Bradford Wargelin (3); Jeremy Drake (4); Xufei Wang (5); Xiao-Li Meng (6)

(1) Center for Astrophysics | Harvard & Smithsonian; (2) Coventry University; (3) Center for

Astrophysics | Harvard & Smithsonian; (4) Center for Astrophysics | Harvard & Smithsonian; (5) Two-Sigma; (6) Harvard University

Energies of flares observed on the Sun and on active stars are invariably distributed as power-laws, indicating that they are driven by a self-organized critical (SOC) process and lack a defining scale. Thus, accurate quantification of these distributions is necessary to understand how coronae are organized in diverse environments. However, there are several impediments to achieving this quantification: detectability decreases for weak flares, causing the distribution to turn over; the dearth of extreme events makes it difficult to extend the nominal power-law to large energies; the conversion from observed count rates to radiative energy lost is not well-characterized, leading to systematic shifts in the distribution slopes due to both plasma temperature and passband effects; and the role of energy partition, which determines how much of the deposited energy goes into conduction loss, CMEs, or radiative loss is not well understood. We will describe methods to account for these issues, and apply them to specific cases like Proxima Cen and the Sun.

The enigmatic nature of stellar magnetic cycles

Sandra Jeffers for the BCool collaboration

Göttingen University

The cyclic large-scale Solar magnetic field is linked to its chromospheric S-index cycle, where it is distinctivly more complex at S-index activity maximum compared to a simple geometry at activity minimum. While activity cycles have been inferred for many hundreds of stars using a variety of techniques, only spectropolarimetric observations can reconstruct the stars large-scale field. As part of the BCool survey of the magnetic fields of cool stars we have been monitoring the large-scale magnetic field of several stars over nearly 15 years. We are starting to see cyclic behaviour in several targets with different masses and rotation rates. In this presentation I will show our results and highlight a few cases where we find surprising cyclic behaviour compared to the Sun.

Disentangling Stellar Activity in an Era of High-Resolution Spectroscopy

John M. Brewer (1); Megan Bedell (2); David Hogg (3)

(1) San Francisco State University; (2) Flatiron Institute; (3) New York University/Flatiron Institute/University of Heidelberg

We describe a new method for mitigating stellar activity in spectroscopic observations. Given that the effect of stellar activity is present enough in spectral data to result in erroneous radial-velocity measurements, it must also be possible to empirically disentangle this effect. We propose a way to empirically model out stellar activity by leveraging high-resolution spectra and data-driven modeling techniques. We use high-resolution (R$\sim$137,000) CHIRON and EXPRES spectra of τ Ceti and ϵ Eridani to show that deviations from symmetric model spectra are visible in activity sensitive lines. These deviations can be tied to changes in activity level of each star and, in the case of τ Ceti, the stellar rotation rate and proposed planetary periods.

Open Clusters orbits using radial velocities and new ages from Gaia DR2.

Laia Casamiquela (1); Caroline Soubiran (2); Tristan Cantat-Gaudin (3); Alfred Castro-Ginard (4)

(1) Laboratoire d'Astrophysique de Bordeaux, Univ. Bordeaux, CNRS ; (2) Dept. Física Quàntica i Astrofísica, Institut de Ciències del Cosmos (ICCUB), Universitat de Barcelona (IEEC-UB)

Thanks to Gaia DR2 and the tremendous improvement in terms of precision of the astrometric measurements, we now have a much more complete census of Open Clusters (OCs) and their members. Gaia DR2 photometry also made possible the computation of ages for most of these OCs by using artificial neural networks. In addition, the numerous large ground-based spectroscopic surveys such as APOGEE, RAVE, GALAH or GAIA-ESO survey, have allowed to dramatically increase the number of stars for which radial velocities are available. Taking advantage of accurate membership lists for more than 2000 OCs, we have gathered radial velocities and ages that allow us to integrate orbits for more than 1400 OCs. We show here the preliminary results of the clusters' orbital properties, and in particular their evolution with age.

Center-to-limb variation of intensity perturbations caused by solar acoustic oscillations

Nadiia Kostogryz (1); Damien Fournier (2); Laurent Gizon (3)

(1) Max Planck Institute for Solar System Research; (2) Max Planck Institute for Solar System Research; (3) Max Planck Institute for Solar System Research/Institut für Astrophysik, Georg-August-Universität Göttingen

In helioseismology it is important understand, at each position on the solar disk, the connection between the p-mode displacement vector and the seismic observable, e.g. continuum intensity. Acoustic modes perturb atmospheric thermodynamical quantities and, in turn, perturb opacity and emergent intensity. We derive analytic expressions for the emergent intensity in a solar atmosphere perturbed by acoustic oscillations, using first-order perturbation theory. Then we compute the emergent intensity by solving the radiative transfer equation in the atmosphere. The adiabatic p-mode eigenfunctions are computed using the ADIPLS eigenvalue solver in a standard spherically-symmetric solar model. Finally, we study the signature of low-degree and high-degree p modes in intensity fluctuations at different positions on the solar disk.

Binary Evolution in the Gaia Era

Emily Leiner; Aaron Geller

CIERA/Northwestern University

Most solar-type stars are in binaries, and many of these binaries will interact over the course of their lives, leading to mass transfer and mergers. Yet, there is much we do not know about the physics of this process, and thus we still cannot make accurate predictions about how binary systems will evolve and end their lives. In the Gaia era, we now have reliable membership information for a large sample of open clusters. Using these as laboratories, there is much we can learn about the impact of binaries on stellar evolution. I will discuss recent results analyzing blue straggler populations in open clusters that demonstrate mass-transfer in older stellar populations may occur

far more often than most models predict. This result has important implications for studying stellar populations, in particular in understanding stellar rotation and other age indicators and calibrating precise gyrochronology relationships.

Search for associations containing young stars (SACY): An updated census of spectroscopic binary systems in the young associations using rotational broadening and high-order cross-correlation features.

S. Zúñiga-Fernández (1); A. Bayo (2); P. Elliott (3); C. Zamora (4); X. Haubois (5); J. M. Corral-Santana (6); J. Olofsson (7); N. Huélamo (8); M. F. Sterzik (9); C. A. O. Torres (10); G. R. Quast (11); C. H. F. Melo (12)

(1) Núcleo Milenio de Formación Planetaria (NPF), Valparaíso, Chile; (2) European Southern Observatory, Vitacura, Santiago de Chile, Chile; (3) Universidad de Valparaiso, Instituto de Física y Astronomía (IFA), Valparaíso, Chile; (4) Department of Physics and Astronomy, York University, Toronto, Canada; (5) Centro de Astrobiología (CSIC-INTA), ESAC Campus, Madrid, Spain; (6) Laboratório Nacional de Astrofísica, Brazil; (7) European Southern Observatory, Garching bei Munchen, Germany

The nearby young moving groups offer one of the best opportunities to study in detail the properties of young stellar and sub-stellar objects thanks to their proximity ($<$ 200 pc) and age ($\sim$ 5 - 150 Myr). Previous works have identified spectroscopic ($<$ 5 au) binaries, close (5-1000 au) visual binaries and wide and extremely wide (1000-100,000 au) binaries in the young associations. In most of the previous analyses, single-lined spectroscopic (SB1) binaries were identified from spectra by variation on radial velocities, however this apparent variation can also be caused by mechanisms unrelated to multiplicity.

We seek to update the spectroscopy binary fraction of our SACY (Search for Associations Containing Young stars) sample taking in consideration identified possible biases in our identification of binary candidates (such as activity and rotation).

We obtained radial velocity measurement using high-resolution spectroscopic observation. The radial velocity values obtained were cross-matched with the literature and were used to revise and update the tight multiplicity fraction for each association. In order to better describe the CCF profile we calculated a set of high-order cross-correlation features to determine the origin of the variations in radial velocities (RV).

We flagged 68 SB candidates from our sample of 427 objects. Our results show a hint towards the higher SB fraction corresponding to the youngest associations (namely, η-Cha $\sim 23^{+6.5}_{-5.6}$ %, TW-Hydrae $\sim 20^{+6.8}_{-6.2}\%$ and β-Pic $\sim 23^{+6.9}_{-6.2}\%$) in contrast with the five oldest which are $\sim 9\%$ or lower.

The new CCF analysis, radial velocity estimates and SB candidates are particularly relevant for membership revision of targets in young stellar associations. These targets would be ideal candidates for follow-up campaigns using high resolution techniques in order to confirm binarity, resolve the orbits and ideally calculate dynamical masses. Additionally, if the results on SB fraction in the youngest associations are confirmed, it could hint towards migration of tight companions beyond $\sim$ 20 Myr.

Rotation-Activity Correlations in M-dwarf Far Ultraviolet Emissions from FUMES

J. Sebastian Pineda; Allison Youngblood; Kevin France

LASP/University of Colorado Boulder

The far ultraviolet spectra of low-mass stars provide access to a host of emission features that probe the stellar upper atmospheric coronal structure. The high-energy emissions produced in these regions of the stellar atmosphere can have a significant impact on planetary systems orbiting these hosts, including atmospheric mass-loss and photochemistry. Understanding the evolution of these emissions is crucial to provide the stellar context across time that shapes current observations of exoplanetary atmospheres. As stars spin down with angular momentum evolution, the strength of this magnetic activity declines over time, with well characterized rotation-activity-age correlations that also serve as probes of the internal magnetic dynamo. However, this connection is mediated by the poorly understood non-thermal heating that powers the emission line features. With the Far Ultraviolet M-dwarf Evolution Survey (FUMES), we have analyzed the FUV spectroscopic behavior of early-to-mid M-dwarfs as they spin down with age. Using features diagnostic of different temperature layers of the atmosphere, we also probed how the canonical rotation-activity correlations manifest from the chromosphere to the corona. We see a possible trend in the correlations with emission line formation temperature, a possible consequence of the nature of the magnetic heating.

Exploring persistent Doppler signals in rapidly-rotating M dwarfs

Paul Robertson for the HPF Team

University of California, Irvine

The recent detection of a candidate exoplanet at the stellar rotation period of the young M dwarf AD Leo places a new emphasis on understanding the persistence and chromaticity of starspot signals for the lowest-mass stars. We have obtained highly precise multi-wavelength Doppler spectroscopy of four rapidly-rotating M dwarfs using the near-infrared Habitable-zone Planet Finder on McDonald Observatory's 10m Hobby-Eberly Telescope, and the optical HIRES spectrometer on the 10 Keck I Telescope. Our Doppler observations are complemented by photometry from Kepler, TESS, and the Las Cumbres Observatory (LCO) network of telescopes. For all four targets, we recover strong RV signals at the stellar rotation period. We will discuss the persistence, chromaticity, and relation to photometry of each.

Pre-main sequence stars in the time domain: insights from CoRoT and Kepler/K2

L. Venuti (1); A.M. Cody (2); L.M. Rebull (3); G. Beccari (4); K2 and CSI2264 collaborators (5)

(1) NASA Ames Research Center; (2) NASA Ames Research Center; (3) Infrared Science Archive, IPAC, Caltech; (4) ESO Garching

High-precision time series photometry provides a unique window into the dynamics of the inner disk regions (<1 AU) around young stars (<5-10 Myr). Exquisite surveys carried out with CoRoT and Kepler have revealed a huge variety of photometric behaviors for young stellar objects, driven by variable mass accretion, stellar magnetic activity, or rapidly evolving circumstellar dust structures. The precision and homogeneity of space-borne data have allowed us, over the past decade, to identify several distinct classes of young star variables, each characterized by different degrees of (a)periodicity and (a)symmetry of the observed flux variations: periodic, quasi-periodic, stochastic, bursters, dippers. This variety of behaviors, observed in each young cluster and star-forming region investigated from space, points to at least two distinct paradigms of star-disk interaction, stable vs. unstable, that may govern different stages of pre-main sequence evolution. As we reached the end of the K2 mission, accurate time domain data for hundreds of young stars are available for virtually every stage of protoplanetary disk lifetimes: surveyed regions include rho Ophiuchi and the Lagoon Nebula (∼2 Myr), NGC 2264 (3-5 Myr, monitored earlier with CoRoT), and Upper Scorpius (5-10 Myr). In this contribution, we discuss the insights provided by these campaigns into the time evolution of the star-inner disk dynamics, and what these observations teach us regarding the stellar and circumstellar dynamics as a function of stellar mass and environmental conditions.

A Stellar Age Dependence of the Planet Radius Valley

Travis A. Berger (1); Daniel Huber (2); Jennifer L. van Saders (3); Eric Gaidos (4); Jamie Tayar (5); Lauren M. Weiss (6); Adam L. Kraus (7)

(1) Institute for Astronomy, University of Hawai'i at Mānoa; (2) Institute for Astronomy, University of Hawai'i at Mānoa; (3) Institute for Astronomy, University of Hawai'i at Mānoa; (4) Department of Earth Sciences, University of Hawai'i at Mānoa; (5) Institute for Astronomy, University of Hawai'i at Mānoa; (6) Institute for Astronomy, University of Hawai'i at Mānoa; (7) Department of Astronomy, The University of Texas at Austin

One of the most exciting exoplanet discoveries in recent years has been the resolution of the planet radius valley, a dip in the occurrence of $Kepler$ exoplanets with short orbital periods at ∼1.9 earth radii. However, the origin of the valley and its relation to planet formation is still heavily debated. The two leading theories, photoevaporation and core-powered mass-loss, predict different timescales and stellar mass dependencies for planet atmospheric loss, making the properties of the host stars critical to discern between them. In this talk, I will present the first evidence for a stellar age dependence of the radius valley based on the homogeneous $Gaia$-$Kepler$ Stellar Properties Catalog, with median fractional precisions of 4% for stellar radius, 7% for stellar mass, and 56% for stellar age for the vast majority of $Kepler$ hosts. In particular, I will show that the fraction of super-Earths to sub-Neptunes increases for stars with ages greater than 1 Gyr and that the planet radius valley increases with stellar mass. Combined, these results provide the first direct evidence for favoring core-powered mass-loss over photoevaporation. The results detailed here demonstrate the potential for transformative characterization of stellar and exoplanet populations using $Gaia$ data.

A circular polarisation survey for radio stars with ASKAP

Joshua Pritchard (1); Andrew Zic (2); Tara Murphy (3); Christene Lynch (4)

(1) University of Sydney; (2) University of Sydney; (3) University of Sydney; (4) Curtin University

M-class dwarf stars are known to exhibit radio flares with intensities orders of magnitude greater than those produced by the Sun. These events often have brightness temperatures in excess of 10^{12} K and high fractional circular polarisation, requiring the operation of a non-thermal, coherent emission process. The flares are generally attributed to either the electron cyclotron maser instability or plasma emission, and are excellent probes of the electron density or magnetic field of the stellar magnetosphere if the emission mechanism can be determined. Most radio-frequency stellar flares have been detected in targeted observations of stars demonstrating prior optical or x-ray flares or chromospheric activity, a selection bias which may impact inference of radio star population statistics.

In this talk I will present results from a circular polarisation survey for radio flare stars in the Rapid ASKAP Continuum Survey (RACS). I used an innovative untargeted circular polarisation search

technique for identifying stellar radio flares, producing a volume-limited sample of the radio-active star population with no other selection bias. After excluding imaging artefacts, active radio galaxies, and pulsars I identify radio emission coincident with 33 known stars, ranging from M-dwarfs through to magnetic early B-type stars. Some of these are well known radio stars such as YZ Cmi and CU Vir, but 22 have no previous radio detection. I will discuss the nature of the radio emission, the implications of these results for the population statistics of radio stars and the application of this search technique to future ASKAP and SKA surveys.

High-resolution spectroscopic parameters of M dwarfs

Terese Olander

Uppsala University

In the search for exoplanets M dwarfs are attractive targets. To be able to assess the habitability of planets around M dwarfs, the atmospheric parameters of the host star need to be accurately determined as well as abundances of individual chemical elements. Recent advances in high-resolution spectroscopy in the near-infrared have opened up the possibility to greatly improve the analysis of M dwarfs.

The method of fitting the observed high-resolution spectra with synthetic spectra has recently been applied by Lindgren et al. (2016, 2017) and Passegger et al. (2018, 2019) using different instruments and theoretical approaches. We present a comparison of stellar parameters derived by Lindgren et al. and Passegger et al. for 11 different stars in common between the two studies. The derived stellar parameters agree within uncertainties for half of the stars but differ for the other half.

We investigate the reasons for the diverging results by comparing synthetic spectra generated for the derived parameters with observed spectra. We present an assessment of non-LTE effects in the parameter range of M dwarfs for some elements and of the quality of the line data. The aim is to validate and improve the method of fitting synthetic spectra to observed spectra for M dwarfs.

Decrypting brightness variations of Sun-like stars with the solar code

Alexander I. Shapiro (1); Sami K. Solanki (2); Natasha A. Krivova (3); Eliana M. Amazo-Gómez (4)

(1) Max-Planck Institute for Solar System Research; (2) Max-Planck Institute for Solar System Research/School of Space Research at Kyung Hee University; (3) Max-Planck Institute for Solar System Research; (4) Max-Planck Institute for Solar System Research.

Considerable effort has gone into using light curves observed by space telescopes (e.g. CoRoT, Kepler, and TESS) for determining important stellar parameters, such as rotation period, inclination, and even surface distribution of magnetic features. In particular, a lot of successful methods have been developed for active stars, whose light curves usually have regular temporal profiles. At the same time these methods fail for the majority of less active stars. For such stars the elaborate configuration of magnetic features and their relatively rapid evolution leads to rather complex light curves and render their interpretation very difficult. The most prominent example of such a star exhibiting a complex light curve is our Sun so that a good understanding of the physical phenomena determining solar variability might be helpful for solving problems posed by stellar data.

We employ an approach similar to that taken by the Spectral And Total Irradiance Reconstruction (SATIRE) model, which was originally developed for the Sun, to synthesise stellar light curves and their power spectra. We demonstrate that the profile of the power spectrum of stellar brightness variations is a very sensitive tool for stellar diagnostic. In particular, we specify the conditions under which the rotation peak in stellar power spectra disappears and show that even in such cases, the stellar rotation period can still be determined from the high-frequency tail of the power spectrum. This allows us to propose a new method for determining rotation periods of low-activity stars, like the Sun. We apply our novel method to Kepler stars with near-solar effective temperatures and report rotation periods of several thousand stars for the first time.

Detecting stellar flares from weak-lined T Tauri stars using the Low-Frequency Array (LOFAR)

A. Feeney-Johansson; S. J. D. Purser; T. P. Ray

Dublin Institute for Advanced Studies

The study of stellar flaring has long been important to understanding the magnetic fields and activity of stars. Young low-mass pre-main sequence stars, also known as T Tauri stars, are frequently associated with high variability and magnetic activity, thought to be caused by flaring activity due to magnetic reconnection. Such flaring activity has been well studied at X-ray wavelengths but is less well documented in the radio band. Additionally, most detections of radio flares from young stellar objects (YSOs) have been at GHz frequencies, where the emission is generally attributed to incoherent gyrosynchrotron emission.

We have recently detected radio flaring from two weak-lined T Tauri stars: KPNO-Tau 14 (0.1 $M_\odot$) and LkCa 4 (0.15-0.30 $M_\odot$), located in the Taurus Molecular Cloud star-forming region. These flares were detected using the Low-Frequency Array (LOFAR) at 150 MHz and marks the first time radio flaring has been detected from YSOs at low frequencies. The emission observed from these flares is highly circularly polarized, with polarization fractions between 60 – 100%. In addition, the brightness temperatures derived for the flares are on the order of 10^{14} – 10^{15} K. Such high polarization fractions and brightness temperatures imply that the emission must be due to a coherent emission mechanism, either plasma emission or electron-cyclotron maser (ECM) emission, the first time such emission has been detected from YSOs.

These detections suggest low-frequency radio observations could be an important method for studying magnetic fields and activity from YSOs. Currently, the Taurus and Perseus molecular clouds are being surveyed for radio emission by LOFAR. From this we hope to find many more similar detections which will be valuable in our understanding of such phenomena.

Calibrating gyrochronology using Galactic kinematics

Ruth Angus (1); Angus Beane (2); Adrian Price-Whelan (3); Jason Curtis (4); Yuxi Lu (5); Elisabeth Newton (6); Jennifer van Saders (7); Travis Berger (8); Rocio Kiman (9)

(1) American Museum of Natural History, Central Park West, Manhattan, NY, USA; (2) Center for Astrophysics | Harvard & Smithsonian, 60 Garden Street, Cambridge, MA 02138, USA; (3) Center for Computational Astrophysics, Flatiron Institute, 162 5th Avenue, Manhattan, NY, USA; (4) American Museum of Natural History, Central Park West, Manhattan, NY, USA; (5) Department of Astronomy, Columbia University, Manhattan, NY, USA; (6) Dartmouth College, Hanover, NH, USA; (7) Institute for Astronomy, University of Hawaï at Manoa, Honolulu, HI, USA; (8) Institute for Astronomy, University of Hawaï at Manoa, Honolulu, HI, USA; (9) Department of physics, CUNY Graduate Center, City University of New York, Manhattan, NY, USA

Gyrochronology, the method of inferring the age of a star from its rotation period, could provide ages for billions of stars over the coming decade of time-domain astronomy. However, the gyrochronology relations remain poorly calibrated due to a lack of precise ages for old, cool main-sequence stars. Now however, with proper motion measurements from Gaia, Galactic kinematics can be used as an age proxy, and the magnetic and rotational evolution of stars can be examined in detail. We demonstrate that kinematic ages, inferred from the velocity dispersions of groups of stars, beautifully illustrate the time and mass-dependence of the gyrochronology relations. We find that magnetic braking efficiency does not always increase with decreasing mass for K dwarfs, which contradicts the standard picture of magnetic braking but adds to the mounting evidence that variable internal angular momentum transport influences stellar spin-down. We present other new features of rotational evolution, and a new Gaussian process gyrochronology relation, that fully captures the complex rotational evolution of cool dwarfs over a range of masses and ages.

XUV Emission, Winds and Superflares from Young Solar Analogs: Implications for the rise of biogenic conditions in the Solar System and exoplanetary systems

Meng Jin (1); Benjamin Lynch (2); Kevin France (3); Manuel Guedel (4); Theresa Lueftinger (5); Sudeshna Boro Saikia (6); Kenji Hamaguchi (7); David Soderblom (8); Oleg Kochukhov (9)

(1) NASA GSFC & American University, DC, USA; (2) SETI, USA; (3) University of California at Berkeley, USA; (4) University of Vienna, Austria; (5) University of Vienna, Austria; (6) NASA GSF, USA; (7) STScI, USA; (8) Uppsala University, Sweden

Observations of solar-like (G-type) stars with ages between 300 – 700 Myrs suggest that the young Sun was a magnetically active star with X-ray and Extreme UV (EUV) forming bright transition region and corona and frequent energetic flares (superflares). These non-thermal outputs produced extreme space weather that significantly contributed to the atmospheric erosion and atmospheric chemistry of terrestrial type planets in the early Solar system. We use the results of our recent coordinated Hubble Space Telescope (HST) observations, XMM-Newton, NICER and spectropolarimetry observations with constraints from the Transiting Exoplanets Survey Satellite (TESS) of a young (600 Myr) solar analog G2V BE Ceti to derive properties of the observed superflare and possible signatures of the emerging active region. We also present the results of a data constrained three-dimensional (3D) magnetohydrodynamic (MHD) Alfven Wave Solar Model (AWSoM) coronal model and discuss the results with the corona and the wind of another young (650 Myr) solar analog, G5V k1 Ceti star at two epochs. Using these two stars as proxies for the young Sun we discuss the implications of the modeled EUV and wind mass fluxes on the atmospheric escape and the rise of biogenic conditions from Venus, Earth and Mars in the first half a billion years and young exoplanets around active G type stars.

Stellar mapping: A Bayesian perspective

Rodrigo Luger

Flatiron Institute

Perhaps the simplest question that one can ask of a distant star is, "What does it actually look like?" Even the best interferometers can only give us limited information about the surfaces of select giant and/or nearby stars. Fortunately, several techniques exist that allow us to indirectly infer what the

surfaces of stars and brown dwarfs look like from precise photometric light curves and high resolution spectral timeseries. In this talk, I will discuss the mathematical theory behind the mapping problem, including its degeneracies and limitations, and present several novel approaches to producing surface maps of stars and brown dwarfs. I will focus particularly on casting stellar mapping as an inference problem, treating it in a Bayesian framework to enable efficient and statistically robust modeling of individual stars and populations of stars. Finally, I will show how these maps can be used to learn about the physics of stellar surfaces and stellar magnetic fields, as well as to better understand the planets these stars host.

Migration of chemical elements inside stars

Ekaterina Semenova (1); Maria Bergemann (2); Morgan Deal (3)

(1) Max Planck Institute for Astronomy; (2) Max Planck Institute for Astronomy; (3) Instituto de Astrofísica e Ciências do Espaço, Universidade do Porto CAUP

It is common to assume that the surface abundances represent the composition of the ISM from which the star was born. However, this assumption is controversial. Recent observational and theoretical studies suggest that individual chemical elements migrate inside the stars. Given the physical diversity of transport processes, the question is: how can we constrain this migration? In this talk, I will touch upon our recent findings, based on high-quality analysis of the Gaia-ESO survey data with 3D Non-LTE models. I will outline the physics behind the transport of elements in star, discuss the constraints that can be obtained from observations, and highlight broader consequences for studies of chemical enrichment of stellar populations in the Milky Way and in other galaxies.

New Results From the Atmospheres of Transiting Brown Dwarfs

Thomas Beatty (1); Adam Burrows (2); Knicole D. Colón (3); Jason L. Curtis (4); James R. A. Davenport (5); Drake Deming (6); Jonathan J. Fortney (7); B. Scott Gaudi (8); Avi M. Mandell (9); Mark S. Marley (10); Benjamin T. Montet (11); Caroline V. Morley (12); Adam P. Showman (13)

(1) University of Arizona; (2) Princeton University; (3) NASA Goddard; (4) Columbia University; (5) University of Washington; (6) University of Maryland; (7) UC Santa Cruz; (8) Ohio State University; (9) NASA Goddard; (10) NASA Ames; (11) University of Chicago; (12) UT Austin; (13) University of Arizona

Observations transiting brown dwarfs provide us with a unique opportunity to directly and independently measure masses, radii, atmospheric properties – and sometimes even ages – for these objects. This can provide critical benchmarks for brown dwarf evolution and atmosphere models, as well informing how we interpret the spectral morphology of field brown dwarfs. I will discuss results from recent atmospheric observations of the transiting brown dwarfs KELT-1b and CWW 89Ab using HST and Spitzer. Phase curve observations of KELT-1b from these two observatories provide a unique way to study cloud formation, by showing clouds as they form on the nightside and breakup on the dayside. Spitzer eclipse observations of CWW 89Ab, meanwhile, show that the dayside is significantly over-luminous compared to evolutionary model predictions at the well-defined cluster age of the system. I will discuss possible solutions, and how these may indicate that CWW 89Ab may have formed via core accretion. Finally, I will describe the potential for JWST observations of transiting brown dwarfs to provide the first direct test of the spectral indices commonly used to estimate surface gravities in field objects.

PBjam: do-it-yourself asteroseismology

Martin Nielsen (1); Guy Davies (2); Warrick Ball (3); Alex Lyttle (4); Oliver Hall (5); Tanda Li (6); Joel Ong (7); Bill Chaplin (8)

(1) University of Birmingham; (2) Stellar Astrophysics Center; (3) New York University Abu Dhabi, Yale University

Asteroseismology is an exceptional tool for measuring fundamental stellar properties. The CoRoT, Kepler and TESS missions have observed thousands of stars that oscillate in a similar way as our Sun. This allows us to place tight constraints on their mass, radius and even age, which are important for understanding stellar structure and evolution, exoplanets and stellar populations in our galaxy. The enormous amount of observations that are and will become available, must be made accessible to the community in an easy and straightforward way. We are developing the PBjam platform for this purpose. PBjam is an open-source Python package for measuring oscillation frequencies of stars, and aims to be fast, easy and automated, allowing users in the wider community to exploit asteroseismic constraints in their studies.

Towards stellar CME observations: Blue asymmetries of Balmer lines during M-dwarf flares investigated with recent multi-wavelength campaign observations

Yuta Notsu (1,2) (1); Adam Kowalski (1,2) (2); Hiroyuki Maehara (3) (3); Kosuke Namekata (4) (4); Satoshi Honda (5) (5); Suzanne Hawley (6) (6); James Davenport (6) (7); Teruaki Enoto (7) (8); Kenji Hamaguchi (8,9) (9); Todd J. Henry (10) (10); Shota Notsu (7) (11); Soshi Okamoto(4) (12); Kai Ikuta (4) (13); Daisaku Nogami (4) (14); Kazunari Shibata (4) (15)

(1) (1) LASP, University of Colorado Boulder; (2) (2) NSO; (3) (3) NAOJ; (4) (4) Kyoto University; (5) (5) University of Hyogo; (6) (6) University of Washington; (7) (7) RIKEN; (8) (8) NASA/GSFC; (9) (9) UMBC; (10) (10) Georgia State University

Flares result from the magnetic energy release in the solar/stellar atmosphere, and they have strong emissions from radio to X-rays. Recent Kepler&TESS photometric data have brought us great amount of knowledge of statistical properties of stellar flares (e.g., Notsu et al. 2019; Gunther et al. 2019), in particular how flare activity changes with age. It has recently become important to investigate how flare activity and the accompanying stellar coronal mass ejections (CMEs) affect planetary atmospheres, but still we have a very small number of observational constraints on energy release processes and the CME occurrence during energetic stellar flares. Several attempts to observe stellar CMEs have been made, but all the results are still controversial and not well-established. Recently, "snapshot" data of Balmer lines (Hα, Hβ) from exoplanet surveys have shown that asymmetric blue-shifted spectra are common among M-dwarfs (Fhurmeister et al. 2018; Vida et al. 2019), and several studies have already started to use them as signatures of stellar CMEs. However, in the case of solar flares, blue-shifted asymmetries of chromospheric (e.g., Balmer) lines can be also caused by flaring dynamic plasma not necessarily related with CMEs (e.g., Canfield et al. 1990; Tei et al. 2018), and similar cases might be possible for M-dwarfs. Current snapshot data are thus not sufficient, and we need more flare spectroscopic observations with high time resolution for understanding how Balmer line blue asymmetries occur during stellar flares and whether these asymmetries are related to stellar CMEs. We have conducted more than 20 nights of multi-wavelength campaign observations of nearby M-dwarf flare stars. The campaign includes optical high-dispersion spectroscopic observations using APO3.5m and SMARTS1.5m, TESS and LCO

optical photometric observations, X-ray&UV data from XMM-Newton and NICER. We find that there are various types of remarkable events: (i) flares with continuous blue asymmetry from flare start to end (Honda, Notsu et al. 2018), (ii) large-amplitude white-light flares with broad wing enhancements of Balmer lines lack clear blue asymmetries, (iii) marginal non-white-light flare enhancements with short-term blue asymmetries, which may be related with mass ejections. Blue asymmetries are possibly common in the case of M-dwarf flares, but properties might be very different among stellar flares, including possible differences between "white-light" flares and "non-white light" flares. In this presentation, we introduce the latest results, and demonstrate the importance to collaborate with solar flare observations.

A Statistical Analysis of Flare Rates Across M Dwarf Parameter Space

Emily Gilbert (1); Tom Barclay (2); Lucianne Walkowicz (3); Josh Schlieder (4); Michele Silverstein (5); Rishi Paudel (6); Elisa Quintana (7); Laura Vega (8); Teresa Monsue (9)

(1) University of Chicago & The Adler Planetarium & NASA GSFC; (2) NASA GSFC & UMBC; (3) The Adler Planetarium; (4) NASA GSFC; (5) NASA GSFC; (6) NASA GSFC; (7) NASA GSFC; (8) NASA GSFC & Vanderbilt University; (9) NASA GSFC

M dwarf stars are known to be highly magnetically active, yet there are limitations to our understanding of their activity. In particular, how flaring varies with parameters such as spectral type and age is not well understood. In order to study the relationship between white-light flare rates and stellar parameters such as age, rotation, and spectral type, we developed software to identify white-light flares in TESS two-minute cadence data. We then model the flares simultaneous with spot modulation using Gaussian Processes in order to derive more accurate flare energy measurements. We present the initial results from our M dwarf flare survey showing how flare rates and energy vary over stellar masses and lifetimes. The evolution of flares with time and as a function of stellar mass are critical to understand M dwarf space weather, including the cumulative impact on small planets in their close-in habitable zones.

Rotation measurements for Eclipsing Binaries

A. C. Mattiuci F. (1); L. de Almeida (2); J. Bouvier (3); M Deleuil (4); J.-D. do Nascimento Jr. (5)

(1) Departamento de Física, Universidade Federal do Rio Grande do Norte, 59072-970 Natal, RN, Brazil; (2) Harvard-Smithsonian Center for Astrophysics, Cambridge, MA 02138, USA; (3) Université Grenoble Alpes, CNRS, IPAG, 38000 Grenoble, France; (4) Aix-Marseille Université, CNRS, CNES, LAM (Laboratoired'Astrophysique de Marseille) UMR 7326, 13388 Marseille, France

Space mission like CoRoT, KEPLER and TESS are designed and launched specifically to find Earth-sized planets orbiting nearby stars. The large field of view features from these satellites allow to observe continuously with high-precision instrumental level a large sample of single stars, as well as eclipsing binary stars. Eclipsing binary systems (EBs) are a small fraction of all the multiple systems. They are fundamental for determining stellar parameters and linked to spectroscopically derived parameters allow us to determine component masses. By observing the orbit of those systems, we can better constrain the physics from theoretical models. In addition, the binary orbit may shift in a regular way ('apsidal motion') causing variation of the eclipse depth and revealing about the internal mass distribution of the stars. Even if some studies of EBs are focused on the

discovery and analysis of the system, only a few are devoted to measure and interpret the rotation rates of these stars. Thus, in this study, we cross-related eclipsing binaries from CoRoT, KEPER and TESS missions with Gaia DR2, and we set up a sample, as big as possible, of binary system within spectral types G and K, and orbiting dwarfs and more evolved stars. Specifically, for the CoRoT mission (our focus now), we present a final sample composed by 144 systems with orbital period and eccentricity already known in the literature. For those stars, by using binary star (ELLC) modeling from Maxted (2016), we confirmed eccentricities for 27 systems. We determined rotational period for 72 systems by using the DRUM TONNES algorithm (de Almeida et al. 2020) which identifies and eliminates transits from the light curve and recover residual rotational modulation. For 3 of them we present here high resolution spectroscopy observations obtained with Gemini Remote Access to CFHT ESPaDOnS Spectrograph (GRACES). Our aim is to measure the rotational periods for a very precise set of eclipsing binaries and analyze the relationship with the orbital period and eccentricity. From these observations we obtained characteristics about mass, synchronization and circularization of the systems, and we discuss pseudo-synchronization, differential rotation and circularization times for those systems. Finally, we conclude by describing prospects of our project and how we will apply our methodology to a database composed by eclipsing binaries observed by the Kepler and TESS satellites.

High resolution spectroscopy of ultracool dwarfs

Michael Gully-Santiago; Caroline Morley

The University of Texas at Austin

Brown dwarf atmospheric "retrieval" techniques and grid-fitting forward model techniques have previously been applied to only low-resolution spectroscopy, or a small subset of echelle spectroscopy. There exists a huge untapped reservoir of high-resolution data, with more coming as new high-resolution spectrographs come online such as IGRINS on Gemini, the upgraded NIRSPEC on Keck, and CRIRES+ on the VLT. These facilities can deliver R=20,000 to 100,000 spectral resolution on ultracool L and T dwarfs in the near-IR. L and T dwarfs serve as bookends for low mass stellar physics, exemplars of degenerate interiors, and analogs to directly imaged exoplanets, uniting these disparate extremes in a single category. With echelle data we can now extract precision surface gravities and vsini, which map onto mass and inclination angle for these nearly-fixed radius dwarfs. We can observe differential "line veiling" as clouds rotate into- and out-of view in multi-epoch observations. We can interogate the depth-resolved temperature pressure-profile in ways that cannot be achieved from low-resolution data alone. The volume, quality, and latent dimensionality of data requires new statistical techniques that our team has pioneered. Here, we present results from our pilot study showing the power of archival Keck NIRSPEC echelle spectra for cloud-free brown dwarfs (Gully-Santiago et al., in prep.). We also present preliminary results from our expansion to more than 100 brown dwarfs spanning M-T spectral types using a new generation of cloudy brown dwarf models.

Confirming the eccentric nature of Kepler 448c using TTV from TESS

Leandro de Almeida; José Dias do Nascimento Júnior

Universidade Federal do Rio Grande do Norte

TTV, or Transit Time Variation, is a great tool for studying extrasolar planets. In addition, by analyzing observations from KEPLER and TESS together we can greatly increase the method power to

discover new planets. In this study, we report a detailed analysis of transit time variations for Kepler 448b (KOI-12b) and we add a new transit event for this star by extracting new transits from the Transit Exoplanet Survey Satellite (TESS). From the Kepler Mission data used with Batman code, we re-analyzed all the 72 KEPLER transits from the short-cadence light curve and 71 transits from the long-cadence light curve. Parallel, by using our own photometrics image tools, we re-extracted the light curve for Kepler$\sim$448 along the TESS Full Frame Images (FFIs), which are taken every 30 minutes. TESS satellite has 21 arcsec pixels and photometric apertures with radius $\sim$1 arcmin, which are often contaminated with multiple background stars. Thus, to avoid inaccuracies from contamination as well as problems from the TESS automatic pipeline reduction, we used a procedure that deals with each subsector of the FFIs that containing our target, and we recalibrated the fluxes by applying our new customized mask to the target in the field of view (FoV). As Kepler$\sim$448b has an orbital period of 19.9 days, TESS light curve presented only a single transit for such a system, and which was used to refine the search for Transit Times Variations (TTV) in a temporal span of approximately 10 years (time lapse between KEPLER and TESS missions). The best solutions from our analysis yield to a third companion with an eccentricity of 0.66 and a mass of about 24 Mjup.

APOKASC-3: Asteroseismology and Rotation in Evolved Cool Stars

Marc H. Pinsonneault for the APOKASC-3 team

Ohio State University, Dept. of Astronomy

The APOKASC consortium is now releasing it's final catalog of red giant asteroseimology for targets in the original Kepler fields. The APOKASC-3 sample of more than 15,000 targets with high-resolution spectroscopy and asteroseismology is a powerful resource for understanding cool stars; there are also 8,000 more dwarf and subgiant stars with spectroscopic data including v sini. Here I focus on what it reveals about angular momentum evolution in post-main sequence stars, and on how well physical models developed for solar analogs fare in this regime.

The TESS M-dwarf opportunity

Karen Collins (1); Tianjun Gan (2); Xavier Bonfils (3); Nicola Astudillo-Defru (4)

(1) MIT; (2) Center for Astrophysics | Harvard & Smithsonian; (3) Tsinghua University; (4) CNRS/Universite Grenoble Alpes; (5) Universidad Catolica de la Santısima Concepcion

The small size of M-dwarfs presents an opportunity for detecting small planets, smaller than planets orbiting larger host stars. In addition, their small size combined with their typical high proper motion allows to directly (as opposed to statistically) rule out false positive scenarios of transiting planet candidates. This validation makes them good targets for high precision radial velocities to measure the planet mass, and other follow-up studies including the characterization of the planet atmosphere or lack thereof. The typical small distance of M-dwarf stars that are bright enough for the above measurements means that Gaia time series astrometry will be sensitive to massive planets and brown dwarfs at wide orbits, with potential partial overlap with objects on orbits that radial velocities will be sensitive to. The M-dwarf opportunity is well aligned with the TESS Mission as it is surveying the entire sky with a redder band than Kepler's. This opportunity was already exemplified by the discovery of LHS 3844. We are now taking advantage of this opportunity to validate and/or confirm small transiting planets orbiting M-dwarfs identified as transiting by TESS. So far this project led to the discovery of GJ 1252 b (Shporer et al. 2020), a 1.2 Earth radius and 2 Earth mass planet orbiting an M3-dwarf at 20.4 pc every 0.52 days, and LHS 1815 b (Gan et al., accepted to AJ), a 1.1 Earth radius planet orbiting an M1-dwarf at 29.9 pc every 3.81 days. LHS 1815 b was also

identified as orbiting a star belonging to the galactic thick disk, making it a rare discovery. The broad theoretical goal of this project is to extend the theoretical and statistical understanding of transiting planets orbiting Sun-Like (FGK) stars, established through the Kepler Mission, to planets orbiting M-dwarfs.

Characterising the 16 Cygni system via the WhoSGlAd method

Martin Farnir (1); Marc-Antoine Dupret (2); Gaël Buldgen (3); Sébastien J.A.J. Salmon (4); Arlette Noels (5)

(1) Université de Liège; (2) Université de Liège; (3) Observatoire de Genève, Université de Genève; (4) Observatoire de Genève, Université de Genève; (5) Université de Liège

As it is one of the brightest systems in the Kepler field of view, the 16 Cygni system has interested scientists for a long time. Indeed, it consists of two solar analogs (sometimes even referred to as solar twins). Therefore, it should provide us with invaluable insight about the history of our Sun. Even though the stars are twins, they show significant differences as the B component was showed to be around four times more Li depleted than the primary star (King et al. 1997). Non standard physical processes are necessary to account for such differences. For instance, Deal et al. (2015) argued that this might be explained by the presence of a Jovian companion around the B component (Cochran et al. 1997). Moreover, the data collected for this system is of unprecedented quality as it has been observed continuously for more than two years with the Kepler satellite. This makes it the ideal test bench, right after our Sun, for stellar models and advanced characterisation techniques such as asteroseismology.

In the present contribution, and taking advantage of the unequalled precision of the data, we will provide a thorough adjustment of the system via the use of the WhoSGlAd method (Farnir et al. 2019). This method relies on asteroseismology which allows, by the adjustment of observed stellar oscillation modes, to provide constraints on the stellar interior. Furthermore, a sharp variation in the stellar structure may create an oscillating signal in the observed spectrum, the acoustic glitch. Such glitches may then provide very localised and invaluable information. Indeed, in solar-like oscillators, it allows to put a constraint on the surface helium abundance which is inaccessible by other means. Moreover, by decoupling the glitch contribution from its smooth counterpart of the spectrum, the method allows to provide very stringent seismic constraints, and, in turn, enables us to constrain the several possible choices of micro and macro-physics used in stellar models. We are then able to draw realistic and accurate stellar parameters ranges. From this, we may get insight on the non standard processes necessary to reproduce the observed data. Finally, the present study may serve as a first step for inverse asteroseismic studies (see for example Buldgen et al. 2016) which require accurate reference models.

Evidence of atomic diffusion in the NGC2420 cluster?

Morgan Deal (1); Ekaterina Semenova (2); Maria Bergemann (3); Aldo Serenelli (4)

(1) Instituto de Astrofísica e Ciências do Espaço, Universidade do Porto CAUP, Rua das Estrelas, PT4150-762 Porto, Portugal; (2) Max-Planck Institute for Astronomy, 69117, Heidelberg, Germany; (3) Kazan Federal University, Kazan 420008, Russian Federation; (4) Institute of Space Sciences (ICE, CSIC), Carrer de Can Magrans S/N, E-08193, Cerdanyola del Valles, Spain; (5) Institut d'Estudis Espacials de Catalunya (IEEC), Carrer Gran Capita 2, E-08034, Barcelona, Spain

Transport of chemical elements in main-sequence stars is still far from understood and leads to large uncertainties in stellar models. The competition between all transport processes leads to variations of stellar abundances and this is only when taking all these processes into account that we will able to explain surface abundances and internal structure of stars. For example atomic diffusion, including the effect of radiative accelerations on individual elements, leads to variations of the chemical composition inside stars as well as the surface abundances evolution. Using the surface abundances of clusters, we are able to quantify the efficiency of macroscopic transport processes competing with atomic diffusion in stars. We present the results obtained with the open cluster NGC2420 and we show that an accurate transport of chemical elements needs to be taken into account in stellar evolution models to be able to explain the more and more precise/accurate surface abundances obtained from observations.

From old metal-poor to young metal-rich cool stars: exploring the parameter space with high-resolution NIR spectroscopy

Cristiano Fanelli

DIFA/University of Bologna & INAF/OAS Bologna

The enhanced sensitivity of IR observations to intrinsically red (i.e. cool) and/or reddened (by dust extinction) stars make a near IR spectrograph the ideal instrument to study the physics, the chemistry and the kinematics of cool giant and supergiant stars in galaxy fields as well as in star clusters. These stars are among the brightest populations in any stellar system: they are easily observable at IR wavelengths out to large distances and also in heavily reddened environments, like the Milky Way inner disk and bulge, where extinction makes optical spectroscopy prohibitive. In this context, I will present first results on the detailed chemistry of cool stars from the SPA - Stellar Population Astrophysics: the detailed, age-resolved chemistry of the Milky Way disk (PI: L. Origlia) Large Programme at the TNG, by using the HR (R=50000) full coverage NIR (0.95-2.4 µm) spectrograph GIANO-B. In particular, by using the GIANO-B spectrum of Arcturus we defined suitable IR diagnostics for deriving atmospheric parameters and we inspected hundreds of atomic and molecular lines for deriving abundances of more than 25 different chemical species , including iron-group, neutron-capture, CNO, alpha and other light elements. We then exploited the methodology developed within the Arcturus-Lab to study young metal-rich red supergiants in the Galaxy disk and a sample of old CEMP (Carbon-Enhanced Metal-Poor) stars in the halo.

Chemical comparison between LMC and Sgr through high-resolution spectroscopy of red giant stars

Alice Minelli

DIFA / University of Bologna & INAF / OAS Bologna

The chemical tagging in red giant stars is a powerful tool to reconstruct the chemical enrichment history of nearby galaxies in the Local Group. The Large Magellanic Cloud (LMC) and the remnant of the Sagittarius (Sgr) dwarf spheroidal galaxy are the closest satellites of the Milky Way (MW). They are excellent laboratories to investigate and unravel star formation and chemical enrichment histories of irregular/dwarf galaxies that have experienced gravitational interactions with the MW. Both galaxies are characterized by a stellar populations which cover a wide range of ages and metallicities. A direct and homogeneous comparison among the chemical patterns of LMC, Sgr and MW is crucial to understand the chemical enrichment history of interacting galaxies, but this kind of study has not been performed so far. Therefore we homogeneously analyzed a sample of high-resolution spectra of metal-rich ([Fe/H] > -1) red giant stars in these three galaxies in order to unveil possible chemical similarities and differences. We derived chemical abundances of nearly 20 elements belonging to the main groups of elements (light, alpha, iron-peak, neutron-capture elements), estimating the role played by Type II and Ia Supernovae and AGB stars to the chemical evolution of these galaxies. We found that LMC and Sgr show very similar chemical abundances in all the analyzed elements. In this talk I will discuss chemical similarities and differences of these two galaxies in comparison to the MW in light of the different formation and evolution of these environments.

UV Spectroscopy of T Tauri Stars with ULLYSES

Will Fischer for the ULLYSES team

Space Telescope Science Institute

The Hubble Space Telescope's Ultraviolet Legacy Library of Young Stars as Essential Standards (ULLYSES) is a Director's Discretionary program of approximately 1,000 orbits that will produce an ultraviolet spectroscopic library of young high- and low-mass stars in the local universe. This presentation addresses the low-mass stars; these are T Tauri stars for which ULLYSES will sample a broad range of stellar masses and accretion rates. In addition to data already in the MAST archive, we will obtain single-epoch COS and STIS spectra of 67 survey targets and time monitoring of 4 prototypical targets. The monitoring targets will be observed four times per rotational period over three periods, with this pattern repeated nine to twelve months later. Observations are expected to begin in Fall 2020. I will discuss our community-driven sample selection and observing plan, with the intent of encouraging meeting participants to collaborate on data analysis and coordinated observations.

Modelling cool star astrospheres

Konstantin Herbst (1); Klaus Scherer (2); Stefan E. S. Ferreira (3)

(1) Christian-Albrechts-Universität zu Kiel; (2) Ruhr-Universität Bochum; (3) Nort-West University Potchefstroom

With upcoming missions like, for example, the James Webb Space Telescope (JWST), we soon will be on the verge of detecting and characterizing Earth-like exoplanetary atmospheres for the first time. Such planets are most likely to be found around smaller and cooler stars. In this study, we present 3D MHD-based astrospheric model efforts comparing our heliosphere to the cool-star astrospheres of the highly active V374 Peg, our nearest neighbor Proxima Centauri, and the inactive LHS 1140.

GIARPS High-resolution Observations of T Tauri stars (GHOsT): connecting atomic and molecular winds in protoplanetary disks.

M. Gangi; S. Antoniucci; K. Biazzo; T. Giannini; B. Nisini

INAF - Osservatorio Astronomico di Roma - Via Frascati 33, 00078 Monte Porzio Catone, Italy

Disk winds are a key ingredient in the evolution of protoplanetary systems, playing a fundamental role for gas dissipation in the inner disk region and in the redistribution of angular momentum. Their

physical properties can be investigated through the emission of atomic or molecular lines detected in high resolution optical/IR spectra of young stellar objects, like the Classical T Tauri stars (CTTs).

This lines usually present a composite profile with an “high-velocity” blueshifted component (HVC, $vp > -40\ km\ s^{-1}$), associated with collimated jets, and a “low-velocity” component (LVC, $vp < -40\ km\ s^{-1}$), attributed to 0.5-10 disk-winds. In addition to this atomic component, IR emission of H_2 roto-vibrational transitions, like the 1-0 S(1) line at 2.12 μm, are often detected in CTTs but the underlying physical processes are still a matter of discussion.

In the framework of the GHOsT (GIARPS High-resolution Observations of T Tauri stars) project, we use the GIARPS instrument at the TNG telescope, that combines high-resolution optical HARPS-N (390-690 nm, R=115000) and infrared GIANO-B (950-2400 nm, R=50000) spectra, with the aim of characterize the atomic and molecular winds in a sample of 36 CTTs of the Taurus-Auriga region. In particular, in this talk we report on a statistical analysis of the kinematic properties of the [OI] 630 nm and H_2 2.12 μm lines and their mutual relationship. We have found that H_2 emission is detected in 50% of the sample while the OI profile has a 100% detection rate. Moreover, the H_2 profile is kinematically correlated with the component at the lowest velocity of the composite [OI] profile and both emissions are found to be originated in regions with size of 0.5-6 au. In this context, different scenarios for the origin of the two emissions will be discussed.

The great dimming of Betelgeuse in 2019-2020

M. Montargès; E. Lagadec; J. Sanchez; E. Cannon; P. Kervella; C. Paladini; A. Matter; F. Cantalloube; L. Decin; A. de Koter; G. Perrin; S. Ridgway; M. Wittkowski; P. Cruzalebes; R. Petrov; P. Gallais; R. Norris; A. Dupree; A. Lèbre; A. Lopez Ariste; B. Lopez; E. Huby; J. Monnier; N. Anugu; S. Kraus; J.-B. Le Bouquin; P. Scicluna; A. Chiavassa; B. Tessore; G. Rau; A. Jorissen; W. Danchi; X. Haubois; F. Millour; A. Meilland; P. Stee; P. Berio; S. Robbe-Dubois; F. Allouche; S. Lagarde.

1: Institute of Astronomy, KU Leuven, Celestijnenlaan 200D B2401, 3001 Leuven, Belgium

Red supergiant stars are important contributors to the chemical enrichment of the Universe. Together with asymptotic giant branch stars, their lower mass counterpart, they contribute ~85% of gas and ~35% of dust to the total enrichment of the interstellar medium. Moreover, the stellar wind has a crucial impact on the final mass, hence on the nature of the compact remnant left after the supernova: a 20 solar mass star can loose up to 60% of its mass during its life. Yet the mechanism at the origin of the red supergiant mass loss remains unknown: there is no physical scenario to lift material from the photosphere up to the dust condensation zone where radiative pressure on small grains can drive the wind.

In November-December 2019, the prototypical red supergiant Betelgeuse started an impressive dimming that brought it to 37% of its average optical brightness in February 2020. It is dimmer than this star has been since quantitative magnitude measurements have been recorded (150 years). We have observed Betelgeuse at high angular resolution during this peculiar event with the VLT/SPHERE, VLTI/GRAVITY and VLTI/MATISSE instruments. I will present the first results of this multi-wavelength and multi-technique campaign and bring them in the context of the study of the red supergiant mass loss.

Lithium 7 depletion and angular momentum transport in rotating solar-like stars

Thibaut Dumont (1); Ana Palacios (2); Corinne Charbonnel (3); Olivier Richard (4); Louis Amard (5); Kyle Augustson (6); Stéphane Mathis. (7)

(1) Observatoire de Genève & LUPM/Université de Montpellier; (2) LUPM/Université de Montpellier; (3) Observatoire de Genève & IRAP/Université de Toulouse; (4) LUPM/Université de Montpellier; (5) University of Exeter; (6) AIM/CEA/CNRS & Université Paris-Saclay & Université Paris-Diderot; (7) AIM/CEA/CNRS & Université Paris-Saclay & Université Paris-Diderot

Robust modelling of solar-like stars is key to understanding the evolution of low-mass stars at different metallicities. So far, no clear consensus appears for which physics is required to reproduce the two main observables: the depletion of lithium 7 with time as observed in open clusters of increasing age and the state of the internal rotation of the Sun. In order to improve stellar modelling, we need to understand these observations and better characterise internal transport processes in the Sun and other stars. Using the stellar evolution code STAREVOL, we compute the lithium abundance as well as the internal rotation profile evolutions from models of rotating stars that include atomic diffusion and additional turbulent diffusion. We test for the first time mixing processes including a rotation-dependent penetrative convection (Augustson et al. 2019, Korre et al. 2019). We then compare the resulting lithium abundances to observations of solar-like stars and solar twins. We discuss the relevance and the efficiency of these different additional transport processes (Dumont et al. in prep).

ODUSSEAS: A machine learning tool to derive effective temperature and metallicity for M dwarf stars

Alexandros Antoniadis-Karnavas (1); Sergio G. Sousa (2); Elisa Delgado-Mena (3); Nuno C. Santos (4); Guilherme D. C. Teixeira (5); Vasco Neves (6)

(1) Instituto de Astrofísica e Ciências do Espaço & Departamento de Física e Astronomia, Faculdade de Ciências, Universidade do Porto; (2) Instituto de Astrofísica e Ciências do Espaço; (3) Instituto de Astrofísica e Ciências do Espaço; (4) Instituto de Astrofísica e Ciências do Espaço & Departamento de Física e Astronomia, Faculdade de Ciências, Universidade do Porto; (5) Instituto de Astrofísica e Ciências do Espaço & Departamento de Física e Astronomia, Faculdade de Ciências, Universidade do Porto; (6) Instituto Federal do Paraná, Campus Foz do Iguaçu, Foz do Iguaçu-PR & Casimiro Montenegro Filho Astronomy Center, Itaipu Technological Park, Foz do Iguaçu-PR

The derivation of spectroscopic parameters for M dwarf stars is very important in the fields of stellar and exoplanet characterization. We present our computational tool ODUSSEAS (Observing Dwarfs Using Stellar Spectroscopic Energy-Absorption Shapes), which is based on the measurement of the pseudo equivalent widths for more than 4000 stellar absorption lines and on the use of the machine learning Python package "scikit-learn" for predicting the stellar parameters. It offers a quick automatic derivation of effective temperature and [Fe/H] for M dwarf stars using their 1D spectra and resolutions as input. The main advantage of this tool is that it can operate simultaneously in an automatic fashion for spectra of different resolutions and different wavelength ranges in the optical. ODUSSEAS is able to derive parameters accurately and with high precision, having precision errors of 30 K for Teff and 0.04 dex for [Fe/H]. The results are consistent for spectra with resolutions between 48000 and 115000 and S/N above 20.

Understanding the correlation between Radial Velocity jitter and photometric variability based on TESS and HARPS observations.

S. Hojjatpanah (1); M. Oshagh (2); P. Figueira (3); N.C. Santos (4); E. M. Amazo-Gómez (5); S. G. Sousa (6); V. Adibekyan (7); O. Demangeon (8); J. Faria (9); J. Gomes da Silva

(10); N. Meunier (11)

(1) Instituto de Astrofísica e Ciências do Espaço, Universidade do Porto, CAUP; (2) Departamento de Fisica e Astronomia, Faculdade de Ciências, Universidade do Porto; (3) Instituto de Astrofísica de Canarias (IAC); (4) Institut für Astrophysik, Georg-August-Universität; (5) European Southern Observatory; (6) Max-Planck-Institut fur Sonnensystemforschung; (7) Univ. Grenoble Alpes

The Radial Velocity (RV) variability caused by the stellar activity is a challenge in the detection and characterization of small-sized exoplanets through RV searches. The relationship between stellar photometric variability and RV jitter can be a powerful method which can help us in better understanding of both phenomena. The current and upcoming high-precision photometric surveys such as TESS and PLATO will provide us thousands of new exoplanet candidates. Defining this relationship can be useful to select the best target with the lowest RV jitter and also to define better observational strategy in RV follow-up program and also in blind RV searches. We will present the relationship between high-precision photometric variability and high-precision RV jitter at different using, for the first time, a relatively large sample of 171 G, K and M dwarfs in the southern hemisphere which have been observed by TESS space mission and HARPS spectrograph. We derived the basic stellar parameters of the stars in the sample and measured directly RV jitter as well as photometric variability using the TESS light curves. We assessed the dependency of the strength of this correlation on some stellar parameters, such as stellar rotation velocity, level of activity (R'HK), and stellar temperature. Our results can provide a new proxy to select the most inactive targets toward search for Earth-class exoplanets. Last but not the least, we also explored all TESS Object of Interest (TOIs), and defined a sub-sample which their host stars should not induced RV jitter in a level which hamper the conformation of their planetary candidates.

Two Faces of the Solar Dynamo: Competing Magnetic Wreath Systems Revealed in Global Simulations

Loren Matilsky; Juri Toomre

JILA & Department of Astrophysical and Planetary Sciences/University of Colorado Boulder

The Sun's dynamo is characterized both by a quasi-regular, 22-year polarity cycle and more irregular temporal modulations such as active longitudes and hemispheric asymmetry. We discuss the results of global MHD simulations of a solar-like convection zone achieving wreaths of intense magnetism that persist coherently amidst turbulent convection. One set of wreaths marches steadily equatorward and regularly reverses polarity (reminiscent of the solar butterfly diagram) and another set exists primarily in one hemisphere or the other and has peak field strengths on opposite sides of the sphere (similar to active longitudes and hemispheric asymmetry). Which set of wreaths is dominant in the simulated dynamos alternates chaotically over long timescales. We discuss these results in light of solar observations, which we argue are consistent with the presence of two distinct states of the solar dynamo operating simultaneously in the deep interior.

CRIRES+: enabling high-resolution near-infrared spectroscopy and spectropolarimetry at the 8-m Very Large Telescope

Alexis Lavail for the CRIRES+ consortium

Uppsala University

CRIRES+ is the fully refurbished and greatly enhanced near-infrared CRyogenic high-resolution InfraRed Echelle Spectrograph (CRIRES) that will be offered to the entire astronomical community in April 2021 (ESO period 107). CRIRES+ combines high spectral resolution and full near-infrared coverage, and enables a variety of long awaited scientific opportunities. In this talk, I will present the excellent and unique capabilities of the instrument, report the latest results from the commissioning campaigns, and highlight early science topics as well as what can be expected from the instrument in its nominal science operation.

CRIRES+ is an adaptive optics fed high-resolution (R=100000) near-infrared spectropolarimeter installed at one of the 8-m unit telescopes of the European Southern Observatory Very Large Telescope in Paranal, Chile. CRIRES+ operates in spectroscopy mode from 0.95 to 5.2 µm (YJHKLM bands) and in spectropolarimetry mode between 0.95 and 2.5 µm (YJHK). The instrument boasts an overall increase in efficiency compared to the original CRIRES, a tenfold increase in simultaneous wavelength coverage thanks to a new cross-dispersed design (now $\sim$150 nm), and improved stability and repeatability. Additionally, a new powerful data reduction pipeline as well as new wavelength calibration capabilities including new gas cells and a Fabry-Pérot etalon will allow to reach a few m/s in RV precision.

The unique combination of the 8-m VLT collecting power, the R=100000 spectral resolution, and spectroscopic coverage up to 5.2 µm makes CRIRES+ a game-changing instrument for the study of exoplanetary atmospheres, stellar magnetism, low-mass objects, and many other science cases.

Solar photosphere magnetization

Véronique Bommier

LESIA, Observatoire de Paris

Solar photosphere magnetization is proposed as able to explain the non-zero divergence of the observed photosphere magnetic field. This observation is very general (see the review by Balthasar, H., 2018, Sol. Phys., 293, 120). In a recent paper (Bommier, V., 2020, A&A, 634, A40), it is shown that what is measured is indeed the magnetic field H, which is related to the divergence-free magnetic induction B by the law B=µ0(H+M), where M is the magnetization. Thermal escape of free electrons from the solar interior, where the electron thermal velocity is much larger than the star escape velocity, is proposed as the source of non-negligible magnetization at the Sun surface. The inner protons however do not escape. As a consequence, they finally retain the escaping electrons, which accumulate at the Sun surface. An electric field would then exist inside the star. Methods to infer B from the H measurements will be investigated. The respective roles of B and H in magnetohydrodynamics will also be investigated.

Activity of cool giants: observing magnetic braking and revival in different phases of evolution

Klaus-Peter Schröder (1); Marco Mittag (2); Jürgen H.M.M. Schmitt (3); Dennis Jack (4)

(1) Departamento de Astronomia de la Universidad de Guanajuato; (2) Universität Hamburg, Sternwarte

By contrast to coronal X-ray detections, chromospheric emission measures are a less biased indicator for magnetic activity among cool giant stars. We review the legacy of Mount Wilson "S-index" observations, and together with our own chromospheric activity monitoring data of bright, cool giants - obtained by the robotic telescope TIGRE in Guanajuato, MEX - and put the observed magnetic activity into context with different phases of stellar evolution. We show empirical evidence for: (1) After magnetic braking on the main sequence and a first revival in the Hertzsprung gap (HG), giant activity suffers from magnetic braking again during central Helium burning, (2) on the upper AGB, chromospheric emission is again on the rise. (3) The activity revival in the HG and on the upper AGB both coincide with core contraction, and in the case of the HG we see the core spinning up. This appears to be a vital clue to how cool giant activity is revived.

Modeling of two CoRoT solar analogues constrained by seismic and spectroscopic analysis

M. Castro (1); F. Baudin (2); O. Benomar (3); R. Samadi (4); T. Morel (5); J. P. Marques (6); J. D. do Nascimento Jr. (7); Y. Lebreton (8); C. Barban (9); P. Boumier (10); J. S. da Costa (11)

(1) Universidade Federal do Rio Grande do Norte; (2) CNRS/Université Paris-Sud; (3) New York University Abu Dhab/NAOJ; (4) CNRS/Observatoire de Paris; (5) Université de Liège; (6) CNRS/Université Paris-Sud; (7) Universidade Federal do Rio Grande do Norte/Harvard-Smithsonian Center for Astrophysics; (8) CNRS/Observatoire de Paris/Université de Rennes; (9) CNRS/Observatoire de Paris; (10) CNRS/Université Paris-Sud; (11) Universidade Federal do Rio Grande do Norte

Solar analogues are important objects for understanding the properties of our own Sun. Evolutionary modeling, combined with seismic and spectroscopic analysis, becomes one of the most powerful methods to characterize stellar intrinsic parameters, such as mass, radius, metallicity and age. However, these characteristics, relevant for other aspects of astrophysics or exosystem physics for example, are difficult to obtain with a high precision and/or accuracy.The goal of this study is to characterize the two solar analogues HD42618 and HD43587, observed by CoRoT. In particular,we aim to infer precise mass, radius, and age, using evolutionary modeling constrained by spectroscopic, photometric, and seismic analysis. These two stars show evidences of being older than the Sun but with a relatively large lithium abundance.We modeled the two solar analogs using two different evolution code: TGEC and CESTAM. Models were computed to re-produce the spectroscopic (effective temperature, metallicity, lithium abundance) and seismic (large separations and small separations) data, and the luminosity of the stars, computed using Gaia parallaxes. Our models infer very similar values of mass and radius for both stars with both codes, within the uncertainties, and reproduce correctly the large and small separations. For HD42618, the two modeling find very similar ages, confirming it is slightly less massive and older than the Sun. However, for HD43587, the two modeling give compatible values in age with a difference of 0.9 Gyr, but confirm it is more massive and older than the Sun. For both stars, we reproduce the lithium abundances with TGEC models by adjusting the parameters of the tachocline.

An ALMA Survey of Chemistry in Disks around Low-Mass M-Stars

Jamila Pegues (1); Karin I. Öberg (2); Jennifer B. Bergner (3); Jane Huang (4); Richard Teague (5)

(1) Center for Astrophysics | Harvard & Smithsonian, Cambridge, MA 02138, USA; (2) Department of Geophysical Sciences, University of Chicago, Chicago, IL 60637, USA

Low-mass M-stars are the most common hosts of planetary systems in the Galaxy. Protoplanetary disks around these cool stars offer a unique opportunity to study how these planets form. We have

carried out the first astrochemical survey of protoplanetary disks around mid-to-late M-stars with the Atacama Large Millimeter/submillimeter Array (ALMA). We use spatially resolved emission from a suite of CO isotopologues and organic molecules, including HCN, C_2H, and H_2CO, to characterize the stellar properties and chemical environments of the five target disks. We detect CO, C_2H, and HCN in all disks, indicating that these disks are rich in gas and organics. In particular, the bright C_2H emission seen in several targets implies elevated C/O ratios in certain disk regions. We find a range of emission morphologies across all detected lines, from central peaks to ring-like structures. These morphologies can be linked to the dust structures, particular chemical pathways, or a combination of the two factors. Disk averaged and radially resolved flux ratios, excitation temperatures, and column densities for the sample appear quite consistent with T Tauri disks, suggesting that the two types of stars may host similar disk chemistry. Finally, we use the brightest molecular lines (i.e., CO isotopologues) to dynamically estimate the stellar masses of the sample, and we compare these results with stellar model predictions for cool stars.

Surface Magnetic Flux Transport and Meridional Flows During Solar Activity Cycle 24

Xudong Sun (1); Junwei Zhao (2); Sushant Mahajan (3)

(1) IfA/University of Hawaii; (2) HEPL/Stanford University; (3) IfA/University of Hawaii

As each solar activity cycle progresses, remnant magnetic flux from active regions (ARs) migrates poleward following the meridional flow. This surface flux transport process effectively cancels and reverses the polarity of the old-cycle poloidal field. We characterize the process during Cycle 24 using 10 years of data from the Helioseismic and Magnetic Imager (HMI) aboard the Solar Dynamics Observatory (SDO). The polarity reversal is north-south asymmetric and episodic. The global axial dipole changed sign in 2013 October; the mean field above 60-degree latitude in the south reversed sign almost 16 months later than the north. We infer the meridional flow speed using two methods: (1) surface magnetic feature tracking, and (2) near-surface time-distance helioseismology. The poleward flow speed from the former monotonically increases with latitude and peaks at $\sim$15 m/s at $\sim$40 degree. A converging flow pattern toward the activity belt is more pronounced in the latter, which is modulated by the sunspot magnetic field and in turn modulates the poleward flux migration. We discuss the differences of these two flow profiles and the non-linear feedback effect of the inflows.

Kinematic signatures of cluster formation by cool collapse

Nicholas J. Wright (1); Richard J. Parker (2); R.D. Jeffries (3); Gaia-ESO Survey team (4)

(1) Keele University; (2) Sheffield University; (3) Keele University

How star clusters form is one of the fundamental and outstanding questions in astrophysics. Combining Gaia proper motions with Gaia-ESO Survey radial velocities and spectroscopic membership indicators, we have performed a 3D kinematic study of the young cluster NGC 6530. From a large sample of members we find that the proper motion velocity dispersion increases with stellar mass. While this trend is the opposite of that predicted if the cluster were developing energy equipartition, it is in agreement with recent N-body simulations that find such a trend develops because of the Spitzer instability. In these simulations the massive stars sink to the centre of the cluster and form a self-gravitating system with a higher velocity dispersion. If the cluster has formed by the cool collapse of an initially substructured distribution, then this occurs within 1–2 Myr, in agreement with our

observations of NGC 6530. We therefore conclude that NGC 6530 formed out of highly extended initial conditions and has since collapsed to form the cluster we see now. This cluster formation model is inconsistent with the idea that all stars form in dense, compact clusters and provides the first dynamical evidence that star clusters can form by hierarchical mergers between subclusters.

Probing radiative levitation in A/F-type pulsators with gravito-inertial asteroseismology

Joey Mombarg (1); Aaron Dotter (2); Timothy Van Reeth (3); Conny Aerts (4)

(1) Institute of Astronomy, KU Leuven; (2) Center for Astrophysics | Harvard & Smithsonian; (3) Institute of Astronomy, KU Leuven; (4) Institute of Astronomy, KU Leuven & Department of Astrophysics, IMAPP, Radboud University & Max Planck Institute for Astronomy

The transport of chemical elements in stars is not well-constrained, already during the core-hydrogen burning phase, thereby introducing large uncertainties on stellar evolution. It is known from first principles that atomic diffusion induces chemical transport on a microscopic scale. The effects of atomic diffusion in intermediate-mass stars can be assessed from gravito-inertial asteroseismology, the study of gravity modes, which probe the stellar interior. In this talk, we will present the modelling of individual frequencies of observed gravity modes in a sample of A/F stars, using models both with and without atomic diffusion, including radiative levitation. Moreover, we compare observed surface abundances with predicted ones from our best-fitting models as an additional test to assess the importance of atomic diffusion in intermediate-mass stars.

COSMIC-DANCE: A comprehensive census of nearby star forming regions

Núria Miret-Roig (1); Hervé Bouy (2); Javier Olivares (3); Phillip A.B. Galli (4); Luis M. Sarro (5); Nuria Huélamo (6); David Barrado (7); Emmanuel Bertin (8); Angel Berihuete (9); Motohide Tamura (10); Jean-Charles Cuillandre (11)

(1) Laboratoire d'astrophysique de Bordeaux; (2) Laboratoire d'astrophysique de Bordeaux; (3) Laboratoire d'astrophysique de Bordeaux; (4) Laboratoire d'astrophysique de Bordeaux; (5) UNED; (6) Centro de Astrobiología (CSIC-INTA); (7) Centro de Astrobiología (CSIC-INTA); (8) Institut d'Astrophysique de Paris; (9) University of Cádiz; (10) University of Tokyo; (11) AIM Paris Saclay

To address any study of star formation and evolution in nearby star forming regions and young open clusters, it is of paramount importance to have a complete and clean sample of members of the region under examination. In this talk, I will present two different algorithms based on Bayesian statistics to obtain members of open clusters. These tools also allow us to obtain a luminosity and mass function consistently propagating the observational uncertainties and the membership probabilities. I will show the results we have obtained in different regions and some of the follow-up investigations we are currently carrying on for these members (e.g. search for debris discs, spectroscopic characterization of substellar objects, and search for exoplanets).

The Stellar Mid-life Crisis: Subcritical Magnetic Dynamos of Sun-like Stars Reconcile Solar-Stellar Activity Observations

Dibyendu Nandy (1); Bindesh Tripathi (2)

(1) Indian Institute of Science Education and Research Kolkata; (2) University of Wisconsin-Madison

Long-term solar magnetic activity reconstructions indicate the solar dynamo operates in two distinct – grand minimum and regular activity – modes. By employing bifurcation analysis of a reduced dynamo model we establish this to be a consequence of dynamo hysteresis. We reproduce the observed bimodal distribution of sunspots, but only for subcritical dynamos. A theoretical framework consistent with this finding explains observations of an abrupt midlife transition in stellar activity, characterized by reduced angular momentum loss rates and breakdown of gyrochronology relations. Our study indicates that an evolving stellar dynamo bridges a diversity of phenomena in solar-like stars across their lifetime without the need of invoking any exotic physics.

Activity and spin evolution of old main-sequence stars with asteroseismic ages

Katja Poppenhaeger (1); Rachel Booth (2); Silva Jarvinen (3)

(1) Leibniz Institute for Astrophysics Potsdam; (2) Queen's University Belfast; (3) Leibniz Institute for Astrophysics Potsdam

Stellar magnetic activity is not only an interesting physical phenomenon in its own right, but is also important for the evolution of exoplanet atmospheres and our statistical ability to detect planets around stars in the first place. The evolution of magnetic activity and rotation versus stellar age can be studied using open clusters for ages of up to a few hundred million years. However, this becomes much more difficult for older cool stars because there are no conveniently nearby old clusters to enable the age determination. An alternative pathway is given through asteroseismic age determinations for individual stars. We have performed a detailed study of coronal and chromospheric magnetic activity in cool stars with ages beyond a gigayear, using only stars with well-determined individual ages. We find that the activity of these stars continues to decline with a slope similar to that seen for younger clusters in the case of chromospheric activity, and with an even steeper slope for coronal activity. We do not see evidence of a sustained higher activity level, as one might expect from rotational studies finding a "coasting"-type behaviour. We argue that this puzzling discrepancy can be explained by the fact that stars with low chromospheric and coronal activity may not produce sufficient rotational modulation in their light curves due to the low contrast of spottedness on their hemispheres and may therefore be missing from rotation versus age studies.

Spectral investigation of V565 Mon star

Hasmik Andreasyan; Tigran Magakian; Tigran Movsessian.

Byurakan Astrophysical Observatory

In this work we present the spectroscopic study of V 565 Mon pre-main-sequence star, which is the illuminating star of Parsamian 17 cometary nebula. Observations were implemented on accomplished with 2.6m telescope in Byurakan Astrophysical Observatory. This was the first investigation of the spectra of V565 Mon in detail for last more than 25 years. Based on estimations of radial velocities and equivalent widths of most prominent lines, V565 Mon did not show outflow of the material, although the possibility of an expanding envelope exists. Based on the comparison of strong absorption Ba II lines (which is not typical for this kind of stars) and also on weak Li line in V565 Mon and for other PMS stars we tried to give more precise spectral classification.

The fundamental parameters of stars from high-precision CHARA/SPICA interferometric measurements: a key to characterize the exoplanetary systems

Nicolas Nardetto (1); Denis Mourard (2); Kévin Belkacem (3); Orlagh Creevey (4); Aurélien Crida (5); Pierre Kervella (6); Yveline Lebreton (7); CHARA/SPICA science group (8)

(1) Université Côte d'Azur, Observatoire de la Côte d'Azur, CNRS, Laboratoire Lagrange, France; (2) LESIA, Observatoire de Paris, France

The core program of CHARA/SPICA interferometer is related to fundamental parameters of stars and planets. The combination of Gaia parallaxes, the high-precision measurement of the transit of exoplanets with the PLATO space mission, and CHARA/SPICA angular diameters will provide the radius of exoplanets with 1% precision. Besides, determining the radii of asterosismic targets will bring constrain on the mass of stars (using 'à la carte' approach or scaling relations), and these measurements will be used to improve stellar evolution models, and, in fine, stellar age. In addition, the imaging capacities of CHARA/SPICA will be used to characterize stellar activity such as binarity, spots, stellar rotation, environment, convection and also limb-darkening. Besides, constraining surface-brightness color relations associated to several parts of the HR diagram is fundamental in order to determine the angular diameter of any non-active stars, even faint, for PLATO, but also for the distance determination of early-type eclipsing binaries (for e.g. in M31 and M33), which is crucial for the calibration of the Hubble constant. One of the main challenges of the CHARA/SPICA instrument (Mourard et al. 2018; https://lagrange.oca.eu/fr/spica-project-overview) is to measure a sample of 1000 stars over three years. Observations are expected to start in 2022.

Precise calibration of surface brightness-colour relations for late-type stars based on interferometric measurements

Anthony Salsi (1); Nicolas Nardetto (2); Denis Mourard (3); Orlagh Creevey (4); Daniel Huber (5); Timothy R. White (6); Vincent Hocdé (7); Frédéric Morand (8); Isabelle Tallon-Bosc (9); Chris D. Farrington (10)

(1) Université Côte d'Azur, OCA, CNRS, Laboratoire Lagrange, France; (2) Institute for Astronomy, University of Hawaii, 2680 Woodlawn Drive, Honolulu, HI 96822, USA; (3) Sydney Institute for Astronomy, School of Physics A28, The University of Sydney, NSW 2006, Australia; (4) Stellar Astrophysics Centre, Department of Physics and Astronomy, Aarhus University, DK-8000 Aarhus C, Denmark; (5) Research School of Astronomy and Astrophysics, Mount Stromlo Observatory, The Australian National University, Canberra, ACT2611, Australia; (6) Université Lyon, Université Lyon1, Ens de Lyon, CNRS, Centre de Recherche Astrophysique de Lyon UMR5574, F-69230 Saint-Genis-Laval, France; (7) The CHARA Array, Mount Wilson Observatory, Mount Wilson, CA91023 USA

Surface brightness-colour relations (SBCRs) are used to derive the stellar angular diameters from photometric observations. They have various astrophysical applications, such as the distance determination of eclipsing binaries or the determination of exoplanet parameters. However, strong discrepancies between the SBCRs still exist in the literature, in particular for early and late-type stars. In order to build the SBCRs, we carefully select interferometric measurements in the JMMC Measured Diameters Catalog (JMDC), considering also additional photometric and stellar activity criteria. We build the SBCRs for F5-K7 II/III, F5-K7 IV/V, M II/III and M V stars. The precision on the derived angular diameters using these SBCRs are of 1.0%, 2.0%, 2.1% and 1.7%, respectively. Our work demonstrates that SBCRs are significantly dependent on the spectral type and the luminosity

class of the star. In order to test our methodology, we have also measured very precisely the angular diameter of 14 stars with the VLTI and CHARA arrays, with different instruments. Through this new set of precise and coherent interferometric measurements, we demonstrate the critical importance of the selection criteria proposed for the calibration of SBCR.

In the Trenches of the Solar-Stellar Connection: UV/X-ray Flux-Flux Correlations for Low-and Moderate-Activity Stars

Thomas Ayres

University of Colorado (Center for Astrophysics and Space Astronomy)

Flux-flux correlations (e.g., X-rays vs. Si III 1206, or H I 1215 vs. C II 1335) trace properties of magnetically-disturbed chromospheres and coronae, and can predict unseen EUV species (i.e., degraded by ISM) crucial to exoplanet radiation impacts. Present study leverages Hubble's Space Telescope Imaging Spectrograph (UV) and Chandra X-ray Observatory for nearby Alpha Cen A (G2V) and B (K1V), and Solar Radiation and Climate Experiment (SORCE) instruments SOLSTICE (UV) and XPS (X-rays) for the Sun (G2V), over full decadal activity cycles of each star. Also included is a recent HST Cosmic Origins Spectrograph far-UV survey of 49 low- to moderate-activity sunlike stars in the North and South Ecliptic polar caps (so-called EclipSS survey), where missions like TESS and eROSITA achieve their deepest exposures. The Sun's new flux-flux correlations conflict with previous stellar surveys (in showing broken power laws and curious inversions in the activity dominance of certain species), but are supported by solar-twin Alp Cen A. Somewhat more active Alp Cen B adheres more closely to the previous paradigm, as do the moderately active EclipSS stars. Implications are presented for the cyclic radiation conditions in our Solar System, as well as for exoplanets around other sunlike stars; and insights into the reasons why UV/X-ray emissions increase systematically with increasing magnetic activity, but eventually "saturate" among the fastest rotators.

How can we find big baby planets around young, active stars?

Alexis Heitzmann (1); Stephen Marsden (2); Pascal Petit (3); Matthew Mengel (4)

(1) University of Southern Queensland; (2) University of Southern Queensland; (3) CNRS/Université de Toulouse; (4) University of Southern Queensland

Although our understanding of how planetary systems come to exist has drastically improved over the last two decades, there is still plenty of research to be made around the formation and evolution of massive, short-orbit exoplanets e.g. hot Jupiters, warm Neptunes. Do they form in-situ or far from their host star and later experience migration? By constraining the occurrence rates of these types of planets in every stage of a star's life, we can better understand their fate and hope to favour one formation/evolution mechanism over another. In this context, it is crucial to estimate the population of these weird planets around young stars. Unfortunately, probing young stars is notoriously difficult due to their strong magnetic activity (or 'jitter') inducing spurious radial velocity (RV) signals that often mask the planet(s) RV signature(s) used to detect them. My presentation will showcase a 2-step process to efficiently characterise hot Jupiters orbiting young and active Solar-type stars. First, I will demonstrate how we can assess the capability of two distinct activity-filtering techniques (Doppler imaging and Gaussian process) by attempting to recover simulated planetary signatures hidden behind real stellar RV data exhibiting large jitter. Utilising these same tools, I'll show you how we can then hunt for hot Jupiters around stars being observed by NASA's new planet-finding

mission TESS, which can then be followed-up with our MINERVA-Australis facility at the Mount Kent Observatory.

Disc tearing in a young T Tauri triple star system with misaligned disk/orbit planes

Stefan Kraus (1); Alexander Kreplin (2); Alison K. Young (3); Matthew R. Bate (4); John D. Monnier (5); Tim J. Harries (6); Henning Avenhaus (7); Jacques Kluska (8); Anna S. E. Laws (9); Evan A. Rich (10); Matthew Willson (11); Alicia N. Aarnio (12); Fred C. Adams (13); Sean M. Andrews (14); Narsireddy Anugu (15); Jaehan Bae (16); Theo ten Brummelaar (17); Nuria Calvet (18); Michel Cure (19); Claire L. Davies (20); Jacob Ennis (21); Catherine Espaillat (22); Tyler Gardner (23); Lee Hartmann (24); Sasha Hinkley (25); Aaron Labdon (26); Cyprien Lanthermann (27); Jean-Baptiste LeBouquin (28); Gail H. Schaefer (29); Benjamin R. Setterholm (30); David Wilner (31); Zhaohuan Zhu (32)

(1) University of Exeter; (2) University of Exeter; (3) University of Exeter and University of Leicester; (4) University of Exeter; (5) University of Exeter; (6) ; (7) University of Exeter and KU Leuven; (8) University of Exeter; (9) University of Michigan; (10) University of Liege; (11) University of North Carolina Greensboro; (12) University of Michigan; (13) University of Exeter and Steward Observatory; (14) Carnegie Institution for Science; (15) The CHARA Array; (16) University of Michigan; (17) Universidad de Valparaiso; (18) University of Exeter; (19) University of Michigan; (20) Boston University; (21) University of Michigan; (22) University of Michigan; (23) University of Exeter; (24) University of Exeter; (25) IPAG/Grenoble and KU Leuven; (26) IPAG/Grenoble; (27) The CHARA Array; (28) University of Michigan; (29) Harvard-Smithsonian CfA; (30) University of Nevada

GW Ori is a T Tauri-star triple system with an inner pair (242 day period) and an outer companion (4217 day period). We monitored the orbital motion of the system over the full 11 years period and derived a full RV+astrometry orbit solution, which reveals that the orbital plane of the inner and outer companion are misaligned with respect to each other. Furthermore, we image the circumtriple disc using ALMA, SPHERE, and GPI and discover three rings in thermal light and an asymmetric structure with radial shadows in scattered light. The inner-most ring is eccentric (e=0.3; 43 au radius) and strongly misaligned both with respect to the orbital planes and with respect to the outer disc. Based on the measured triple star orbits and disc properties, we conducted smoothed particle hydrodynamic simulations which show that the system is susceptible to the disc tearing effect, where the gravitational torque of the misaligned companion tears the disc apart into distinct rings that precess independently around the central objects. The ring might offer suitable conditions for planet formation, providing a mechanism for forming wide-separation planets on highly oblique orbits. Modeling the scattered light signatures and the shape of the shadows cast by the misaligned ring allows us derive the shape and 3-dimensional orientation of the disc surface, revealing that the disc is strongly warped and breaks at a radius of about 50 au.

Predicting Long Rotation Periods of TESS Stars with 27-day light curves Using Random Forest

Yuxi (Lucy) Lu (1); Ruth Angus (2); Marcel Agueros (3); Melissa Ness (4); Kirsten Blancato (5)

(1) Columbia University; (2) AMNH & Flatiron Institute & Columbia University; (3) Columbia University; (4) Columbia University; (5) Columbia University

The rotation period of a main-sequence star is closely associated with its other stellar properties, particularly its age, mass and surface gravity. Stellar rotation periods can therefore be used to age-date stars and planetary systems via gyrochronology. In addition, the rotation period of a planet host is useful for mitigating the impact of magnetic activity on radial velocity measurements, and for determining the magnetic environment and 'space weather' of planetary systems. With the Transiting Exoplanet Survey Satellite (TESS), billions of stars will be observed. However, most of them will only be observed for 27 contiguous days in a year and this short observing time makes it difficult to measure rotation periods with traditional methods such as periodograms. This is especially problematic for M-dwarfs, which are ideal candidates for exoplanet search, but they rotate slowly and a large fraction of their rotation periods could exceed 27 days. Here we present a new method, astraea, that uses a random forest algorithm that is able to predict long rotation periods from short light curves. We are able to predict rotation periods from Kepler 4-year light curves with $\sim$ 10% median absolute deviation (MAD) and after training our model on calculated features from 27-day light curves, along with other stellar properties from Gaia, we are able to predict rotation periods smaller than $\sim$ 50 days from 27-day light curves with $\sim$ 50% MAD.

Hidden magnetic fields of young suns

O. Kochukhov (1); T. Hackman (2); J.J. Lehtinen (3); A. Wehrhahn (4)

(1) Department of Physics and Astronomy, Uppsala University, Sweden; (2) Department of Physics, University of Helsinki, Finland; (3) Max Planck Institute for Solar System Research, Germany

Global magnetic fields of many solar-like stars have been detected with circular polarisation measurements and mapped with Zeeman-Doppler imaging. However, due to cancellation of opposite field polarities, polarimetry captures only a tiny fraction of the magnetic flux and cannot reliably assess the total magnetic field if it is dominated by a small-scale component. The analysis of Zeeman broadening in high-resolution intensity spectra can reveal these hidden complex magnetic fields. Historically, there were very few attempts to obtain such measurements for G dwarf stars due to the difficulty of disentangling the Zeeman effect from other broadening mechanisms affecting spectral lines. We have developed a powerful diagnostic method for measuring total magnetic fluxes based on relative intensification of optical Zeeman-sensitive absorption lines. By using this technique, we obtained 78 field strength measurements for 15 Sun-like stars, including some of the best-studied young solar twins. Here we present results of these new Zeeman measurements and discuss emerging trends of the field strength with stellar age, rotation, chromospheric and coronal emission. Comparing our results with the spectropolarimetric analyses of global magnetic fields, we demonstrate that ZDI typically recovers less than 1% of the magnetic field energy. We discuss consequences of this major discrepancy between different magnetic diagnostic methods for understanding of cool-star magnetism and propose pathways for developing empirical stellar magnetic field models capable of self-consistent treatment of both large- and small-scale fields.

Ultraviolet Observations of Exoplanet Host Stars: Recent Results and the Landscape for the Next Two Decades

Kevin France; Allison Youngblood

University of Colorado

Ultraviolet spectroscopy is a primary tool for probing the hot atmospheres of cool stars (spectral types F – M). The 10 – 320 nm ultraviolet bandpass contains key diagnostics of the full temperature range from the chromosphere to the corona, is the most sensitive bandpass for stellar flares

studies, and can provide direct constraints on stellar coronal mass ejections. After their emission from the star, high-energy photons and particles regulate the atmospheric temperature structure and photochemistry on orbiting planets, influencing the long-term stability of planetary atmospheres and driving atmospheric photochemistry. As the field of exoplanet characterization has grown over the past decade, so have large ultraviolet survey programs targeting cool stars.

In this talk, I will give an overview of recent key results from ultraviolet studies of cool stars (primarily with the Hubble Space Telescope), with an emphasis on planetary implications, including the production of "false positive biomarkers" and atmospheric escape. I will conclude by presenting the landscape for stellar and exoplanetary investigations utilizing ultraviolet observations over the next two decades. Missions of all sizes have important roles to play in this area: I will highlight planned or proposed missions ranging from cubesats and smallsats (CUTE, SPARCS, and SPRITE) to mid-sized missions (Probe and Explorer class; CETUS and ESCAPE) to flagships (LUVOIR and Habex).

Most, but not all nearby, young G- and K-stars belong to known moving groups

Alex Binks; Rob Jeffries; Nick Wright

Keele University

In the past three decades several hundred nearby members of young moving groups (MGs) have been identified, but there has been little systematic effort to quantify or characterise young stars that do not belong to previously identified MGs. In this talk I describe our efforts to quantify the fraction of young, nearby stars that belong to known MGs, and discuss the various criteria used to assess MG membership. Using a kinematically unbiased sample of young (< 125 Myr), lithium-rich, low-mass ($0.5 < M/M_{\odot} < 1.0$) stars within 100 pc, we find that $\sim 50 - 70$ per cent are associated with known MGs (depending on the criteria used for membership). The remainder are more broadly dispersed in velocity space, with no obvious concentrations or grouping in velocity or position. The mass distributions of the MG members and non-MG stars is similar, but the non-MG stars are older on average. I discuss several explanations for the origin of the non-MG population.

The Sun: past, present, and near future in the context of integral theory

Elena A. Kadyshevich (1); Victor E. Ostrovskii (2)

(1) Obukhov Institute of Atmospheric Physics; (2) Karpov Institute of Physical Chemistry

The suggested short lecture contains science-based answers to the below-formulated questions. Some of these questions and answers to them are first formulated by us in (Elena A. Kadyshevich, Victor E. Ostrovskii, Adv. Plasma Astrophys., Cambridge, UK, 6 (2011) 95-101), the others are formulated later in our publications. Presently, we generalize the updated answers in the context of an integral theory. (1) What is the cause of the isotopic anomalies around the Sun, in the Solar System (SS) space, and in the SS objects? (2) What is the mechanism of formation of each of known isotopes? (3) Is one or more than one nebula the progenitrix for the SS, and why are the planets principally different? (4) What are the cause and nature of solar protuberances (and of those at the red dwarf DG CVn, 2014)? (5) What is the cause of the temperature increases from solar spots to photosphere and from photosphere to corona? (6) Why are the orbits of most of the biggest celestial bodies located within a belt along the ecliptic plane? (7) Why don't powerful protuberances

explode the Sun if the solar light and heat energy result from fusion reactions that occur under Sun's radiation zone and if the protuberances result from thermonuclear explosions? (8) Why is a so high difference between the solar angular momentum and the sum of planetary angular momenta? (9) What is the cause of approximate periodicity of the protuberance activity events? (10) Why are the sunspot regions attractive for protuberances? (11) What is the cause of acceleration of solar protuberances in flight? (12) Why do protuberances consist of a multitude of differentiated jets and are of the arch-form, pole-form, horn-form, etc? (13) What is the connection between the solar activity and the periodical Earth's mass extinctions? (14) What hazards can the Sun bring in future?

Spectral library of age-benchmark low-mass stars and brown dwarfs

N. Lodieu (1); V. J. S. Béjar (2); M. R. Zapatero-Osorio (3); S.Boudreault (4); M. Bonnefoy (5)

(1) Instituto de Astrofísica de Canarias; (2) Univ. de La Laguna; (3) Centro de Astrobiología (CSIC-INTA); (4) Max-Planck-Institut für Sonnensystemforschung; (5) Université Grenoble Alpes

In the past years, some extremely red brown dwarfs were found. They were believed to have low surface gravity, but many of their spectral characteristics were similar to those of high surface gravity brown dwarfs, showing that youth spectral characteristics are poorly understood. We aim to test surface gravity indicators in late-M and early- L brown dwarf spectra using data obtained with the X-shooter spectrograph at the Very Large Telescope. We selected a benchmark sample of brown dwarfs members of Chamaeleon I ($\sim$2 Myr), Upper Scorpius (5-10 Myr), Pleiades (132$\pm$27 Myr), and Praesepe (590-790 Myr) with well-constrained ages, and similar metallicities. We provided a consistent spectral classification of the sample in the optical and in the near-infrared. We measured the equivalent widths of their alkali lines, finding that they have a moderate correlation with age, especially for objects with spectral types M8 and later. We used spectral indices defined in the literature to estimate surface gravity, finding that their gravity assignment is accurate for 75% of our sample. We investigated the correlation between red colours and age, finding that after $\sim$10 Myr, the colour does not change significantly for our sample with spectral types M6.0-L3.0. In this case, red colours might be associated with circumstellar disks, ring structures, extinction, or viewing angle. Finally, we calculated the bolometric luminosity, and J and K bolometric corrections for our sample. We found that six objects are overluminous compared to other members of the same association. Those objects are also flagged as binary candidates by the Gaia survey.

Using Machine Learning to Uncover the Relationship between Spots and Flares

Adina D. Feinstein (1); Benjamin T. Montet (2); Megan Ansdell (3); Brian Nord (4); Maximillian N. Günther (5)

(1) University of Chicago; (2) University of New South Wales; (3) Flatiron Institute; (4) Fermi National Accelerator Laboratory & Kavli Institute for Cosmological Physics; (5) Massachusetts Institute of Technology

In general, studies of flare detection have relied on accurate removal of spot modulation (detrending) and statistical outlier heuristics. By using these methods, results are incomplete to low flare energies. As flares exhibit similar decay shapes, convolutional neural networks (CNNs) have the potential to be trained to recognize this characteristic without detrending the light curve beforehand, allowing for a more complete low energy flare identification. Understanding where flares occur with

respect to a spot group phase can provide a more detailed picture of surface spot coverage of other stars, as we see more flares near more spots on the Sun. By identifying flares in light curves of stars with strong spot modulation, we can hope to begin to understand overall spot coverage across spectral types. Several recent studies have presented conflicting results on flare occurrence as a function of spot grouping phase: one that flares show no preference and another suggesting low energy flares preferentially occur on the spottier side of the star. I will present the results of applying a CNN to TESS two-minute data of 1500 young (< 300 Myr) stars observed throughout the entire Southern Hemisphere. I will discuss the relationship between flare amplitude and spot grouping phase, spectral type, and age and compare the flare identified with the CNN to those identified by previous methods. The CNN presented is part of a new open-source package, `stella`, available for community use.

A New Understanding of Magnetic Stellar Evolution

Travis Metcalfe (1); Ricky Egeland (2); Jennifer van Saders (3)

(1) Space Science Institute; (2) High Altitude Observatory, NCAR; (3) Institute for Astronomy, University of Hawaii

Over the past few years, strong evidence has emerged that something unexpected occurs in the evolution of stellar magnetism near the middle of main-sequence lifetimes. For solar-type stars this transition begins near the age of the Sun, when rotation becomes too slow to imprint Coriolis forces on the global convective patterns, reducing the shear induced by differential rotation, and disrupting the large-scale dynamo. From the best data currently available, the Sun appears to have entered this phase several hundred million years ago, just as life was emerging from the oceans onto land. Younger stars bombard their planets with radiation and charged particles that are hostile to the development of complex life, but older stars quiet down substantially and provide a more stable environment. I will summarize the latest evidence for this magnetic transition from recent X-ray and Zeeman Doppler measurements, outline our current understanding of its likely origin, and speculate on the implications for planetary habitability.

A 5D map of the nearest open clusters from high-mass stars down to the substellar regime

Nicolas Lodieu (1); Richard Smart (2); Antonio Pérez-Garrido (3); Roberto Silvotti (4)

(1) Instituto de Astrofisica de Canarias (IAC), Tenerife, Spain; (2) Osservatorio Astrofisico di Torino, Torino, Italy; (3) Universidad Politecnica de Cartagena, Murcia, Spain; (4) Osservatorio Astrofisico di Torino, Torino, Italy

We present a 5D map of four of the nearest clusters to the Sun: Alpha Persei (d$\sim$178 pc, 85 Myr), the Pleiades (d$\sim$135 pc; 125 Myr), the Hyades (d$\sim$47 pc; 650 Myr; Lodieu et al. 2019a), and Praesepe (d$\sim$187 pc; 590 Myr; Lodieu et al. 2019b). We identified bona-fide kinematic members from high-mass stars down to the hydrogen-burning limit and below (depending on the distance and age of the cluster) in the second data release of Gaia. We revised the physical sizes of the clusters, and inferred updated mean distances and velocities. We derive the luminosity and mass functions and compare them to the log-normal form of the Chabrier field mass function. We also looked at the 3D spatial distribution of members and produced movies of the new members in 3D space (see links below). We find that high-mass stars tend to be located in the central regions of the clusters while low-mass stars are more frequent beyond the half-mass radii. We clearly confirm the presence of

a stream in the Hyades and the Pleiades. We also compare the age of these clusters, from the literature, with the ages that we obtain from a few white dwarfs belonging to the clusters.

Link to the movies: https://www.dropbox.com/s/19m4q08eenkzq8z/animation_Hyades_30pc.mp4?dl=0
https://www.dropbox.com/s/l109tqfwiylr5pp/animation_Pleiades_tidal_radius.mp4?dl=0
https://www.dropbox.com/s/3mefy8f9idn4eoi/animation_Praesepe_tidal_radius.mp4?dl=0
https://www.dropbox.com/s/kn6stpuek5oq9vh/animation_APer_tidal_radius.mp4?dl=0

Gravitational Waves for Measuring Hubble's Constant in the Accelerating Universe

Rajesh Kumar Dubey

Lovely Professional University, India

There could be different ways for observations and calculations for Hubble's Constant. These methods primarily include estimation from the cosmic microwave background and measurement from distance ladder using standard sirens. After the detection of Gravitational Waves and the modern technology for their advanced sensitivity, the measurement of Hubble's Constant has attained a new platform. The detection of GW170817 in both gravitational waves and electromagnetic waves heralds the age of gravitational-wave multi-messenger astronomy. On 17 August 2017 the Advanced Laser Interferometer Gravitational-wave Observatory (LIGO) and Virgo detectors observed GW170817, a strong signal from the merger of a binary neutron-star system. Less than 2 seconds after the merger, a gamma-ray burst (GRB170817A) was detected within a region of the sky consistent with the LIGO-Virgo-derived location of the gravitational-wave source. This sky region was subsequently observed by optical astronomy facilities resulting in the identification of an optical transient signal within $\sim$10 arc sec of the galaxy NGC4993 These multi-messenger observations allow to use GW170817 as a standard siren the gravitational-wave analog of an astronomical standard candle , to measure the Hubble constant. This quantity, which represents the local expansion rate of the Universe, sets the overall scale of the Universe and is of fundamental importance to cosmology. This measurement combines the distance to the source inferred purely from the gravitational-wave signal with the recession velocity inferred from measurements of the redshift using electromagnetic data. This approach does not require any form of cosmic "distance ladder"; the gravitational-wave (GW) analysis can be used to estimate the luminosity distance out to cosmological scales directly, without the use of intermediate astronomical distance measurements. Additional standard-siren measurements from future gravitational-wave sources will provide precision constraints of this important cosmological parameter.

Spatially resolved stellar disks at hyper-high spectral resolution: Toward Earth-like exoplanet detection

Dainis Dravins (1); Hans-Günter Ludwig (2)

(1) Lund Observatory, Sweden; (2) ZAH - Landessternwarte Heidelberg, Germany

A challenge in highest-precision spectroscopy is to find 'truly' Earth-like exoplanets. While instrumental precisions are close to being reached, limitations arise in the complexities of spectral-line formation. Radial motion, as measured by wavelength shifts, becomes somewhat ambiguous due to spectral-line asymmetries, induced by gas flows in the stellar atmosphere. Signatures differ between different types of lines, change between stars, vary across stellar disks, are modulated by magnetic activity, and depend on spectrometer performance. This project is to study the detailed physics of such line alterations (rather than, e.g., empirical correlations).

Spectroscopy across spatially resolved stellar disks is possible using transiting exoplanets as spatial probes (Dravins et al., 2017ab; 2018), permitting to test center-to-limb stellar hydrodynamics in stars also other than the Sun. Additional bright target stars will likely be found in ongoing exoplanet surveys, and simulations are in progress to identify strategies for their observation.

From a grid of 3-dimensional hydrodynamic CO5BOLD model atmospheres for solar-metallicity dwarf stars (T-eff 3960–6730 K), complete synthetic spectra have been computed (H.-G.Ludwig, L.Koesterke, C.Allende Prieto, S.Bertran de Lis, B.Freytag & E.Caffau, in prep., 2020). At hyper-high spectral resolution (R exceeding one million), some 3 million spectral data points span ultraviolet to infrared, and for each of several center-to-limb locations across stellar disks (the term 'hyper-high' is adopted since 'ultra-high' is commonly used for lower-resolution spectra). Hyper-high resolution is required to fully resolve intrinsic line asymmetries. To segregate those from blends, and also to obtain absolute convective wavelength shifts irrespective of errors in laboratory wavelengths, these 3-D spectra are matched against similar hyper-high resolution spectra from 1-D models. There, unblended lines appear symmetric at their nominal laboratory wavelengths, and the differences to 3-D profiles segregate effects arising in dynamic photospheres.

Synthetic spectra of different spectral types are surveyed to identify unblended lines with different strengths, excitation potentials, ionization levels, and magnetic sensitivities, each of which contribute characteristic (but different) signatures of apparent Doppler shifts. The hyper-high resolution data are degraded to ordinary 'high' and 'ultra-high' spectrometer values to appreciate what signatures may realistically be observed. An adequate understanding of both line formation and of spectrometer performance should enable to disentangle effects arising in stellar atmospheres from those induced by even small Earth-like exoplanets in Earth-like orbits.

Characterizing Differential Rotation with Tides in Eclipsing Binaries

Adam S. Jermyn (1); Jamie Tayar (2); Jim Fuller (3)

(1) Center for Computational Astrophysics, Flatiron Institute; (2) Institute for Astronomy, University of Hawaii & Hubble Fellow; (3) TAPIR, California Institute of Technology

Over time, tides synchronize the rotation periods of stars in a binary system to the orbital period. However, if the star exhibits differential rotation then only a portion of it can rotate at the orbital period, so the rotation period at the surface may not match the orbital period. The difference between the rotation and orbital periods can therefore be used to infer the extent of the differential rotation. We use a simple parameterization of differential rotation in stars with convective envelopes in circular orbits to predict the difference between the surface rotation period and the orbital period. Comparing this parameterization to observed eclipsing binary systems, we find that in the surface convection zones of solar-like stars in short-period binaries there is very little radial differential rotation, with $|r\partial_r \ln \Omega| < 0.02$. This holds even for longer orbital periods, though it is harder to say which systems are synchronized at long periods, and larger differential rotation is degenerate with asynchronous rotation.

Superflares and Variability in Solar-Type Stars with TESS

Lauren Doyle; Gavin Ramsay; J. Gerry Doyle

Armagh Observatory and Planetarium

Further to our work involving the rotational phase of flares on M dwarfs, we have now extended our research into solar-type stars using TESS. Superflares on solar-type stars has been a rapidly developing field ever since the launch of Kepler. In this talk, we present a statistical analysis of stellar flares on solar-type stars made using photometric data in 2-min cadence from TESS of the whole southern hemisphere (Sectors 1 – 13). We derive rotational periods for all stars in our sample, identify 1980 stellar flares from the 209 solar-type stars with energies in the range of $10^{31} - 10^{36}$ erg (using the solar flare classification, this corresponds to X1 - X100,000) and conduct an analysis into their properties. We investigate the rotational phase of the flares and find no preference for any phase suggesting the flares are randomly distributed. As a benchmark, we use GOES data of solar flares to detail the close relationship between solar flares and sunspots providing a unique insight into the findings from our solar-type sample. Additionally, two of our stars were observed in the continuous viewing zone with lightcurves spanning one year, as a result we examine the stellar variability of these stars in more detail.

The Sun as a young star: reproducing the X-ray cycle of ϵ Eridani with solar magnetic structures

M. Coffaro (1); B. Stelzer (2); S. Orlando (3)

(1) Institut fuer Astronomie und Astrophysik Tuebingen (IAAT); (2) INAF - Osservatorio Astronomico di Palermo; (3)

ϵ Eridani is a young solar-like star with a ~ 3 yr X-ray activity cycle, detected by us for the first time in a dedicated *XMM-Newton* long-term monitoring campaign. During an activity cycle magnetic structures rise to the stellar surface where they evolve and decay. On the Sun, these structures were spatially and temporally resolved and traced throughout its 11-yr cycle. However, the surface of stars (other than the Sun) can not be spatially resolved with present-day X-ray instruments. We have, thus, developed a novel technique which allows us to reproduce the variability of the X-ray emission of the star in terms of time-variations in the coverage of the corona with the same kind of magnetic structures that are observed on the Sun: active regions (ARs), cores of active regions (COs) and flares (FLs). In this talk, I present this new method and the results we obtained for the case of ϵ Eridani. Our approach is to simulate a grid of emission measure distributions (EMDs) derived from the analysis of regions observed in the solar corona to artificially reproduce a solar-like corona with the physical characteristics of ϵ Eridani. The three types of magnetic structures are allowed to contribute to the total coronal EMD with varying area coverage fraction. Thus, from a comparison between these pseudo-solar EMDs and the observations of ϵ Eridani, we are able to associate to each state of the X-ray activity cycle of ϵ Eridani the percentage of ARs, COs and FLs on the corona of the star. One main finding is that the average flare EMD of ϵ Eridani is cooler than that of the Sun. We explain this as the flares lasting longer, suggesting a weaker radiative cooling of the corona which is supported by the low metallicity of ϵ Eridani. The observed amplitude of the X-ray luminosity in the cycle of ϵ Eridani is much smaller than on the Sun. Our analysis provides a physical explanation for this: the simulated EMDs indicate that in all phases of the X-ray cycle a large portion of the corona of ϵ Eridani is covered by active structures. Therefore, there is little space for adding further magnetic structures in the cycle maximum. In the future, this method will be applied to other stars providing an important contribution to better understand the solar-stellar corona connection.

Measuring Stellar Rotation in the K2 Sample

Tyler Gordon (1); James R. A. Davenport (2); Ruth Angus (3); Eric Agol (4); Daniel Foreman-Mackey (5)

(1) University of Washington; (2) University of Washington; (3) AMNH/Flatiron Institute; (4) University of Washington; (5) Flatiron Institute

We use a combination of techniques to measure periodicity in over 200,000 K2 light curves and identify nearly 4,000 stellar rotation periods. To robustly measure rotation periods we use both the autocorrelation function and Gaussian process regression with a quasi-periodic kernel function. We conduct an MCMC analysis with a Gaussian process model which allows us to estimate uncertainties for kernel hyperparameters, including the rotation period. We detect the rotation period bimodality first found in the Kepler field by McQuillan et al. (2013). Ours is the first robust detection of the bimodality for stars outside of the Kepler field. We explore the possible origins of this bimodality and argue in favor of the interpretation that the feature arises due to a departure from the Skumanich spin-down law. Data products resulting from this work, consisting primarily of estimates of periodicity and associated uncertainties for all K2 stars, will be made available to the community.

The Evolution of Solar Angular Momentum Loss and its Connection to Other Sun-like Stars

Adam J. Finley (1); Sean P. Matt (2); Victor See (3); Siddhant Deskmukh (4); Amy Hewitt (5); Mathew Owens (6); Chi-Ju Wu (7); Rui Pinto (8); Victor Réville (9); SWEAP team (10)

(1) University of Exeter; (2) University of Exeter; (3) University of Exeter; (4) University of Exeter; (5) University of Exeter; (6) University of Reading; (7) MPI für Sonnensystemforschung; (8) IRAP, Université Toulouse; (9) IRAP, Université Toulouse; (10) Various Institutions

The rate at which the solar wind extracts angular momentum from the Sun has been predicted by theoretical models for many decades, and yet we lack a conclusive measurement from in-situ spacecraft. By combining numerical simulations and in-situ measurements, we estimate the angular momentum-loss rate in the solar wind. This provides a valuable constraint on how the rotation periods of Sun-like stars at, or older than, the age of the Sun evolve. I show how the solar angular momentum-loss rate evolves on a range of timescales from the solar magnetic cycle, to the millennial variations inferred by cosmogenic radionuclide records. Complementary information can be gained by studying other Sun-like stars, which show the Sun in context. For example, it is known that the rotation rates of Sun-like stars follow a tight relationship with age. This allows us to evaluate their angular momentum-loss rates, without any knowledge of stellar wind physics, and produce an independent prediction of the current solar angular momentum-loss rate to compare with our numerical and data-driven estimation. These values are finally discussed in context with the recent observation from Parker Solar Probe, which show the angular momentum flux in the solar wind to be more complicated than previously thought. It is hoped that in future, a combination of observations from Parker Solar Probe and Solar Orbiter may be able to better constrain the solar angular momentum-loss rate.

Deep mixing due to convective penetration during the red giant branch luminosity bump

Jane Pratt (1); Isabelle Baraffe (2); Mary Geer Dethero (3); Kara Gartner (4); MUSIC team (5)

(1) Georgia State University; (2) University of Exeter; (3) Georgia State University; (4) Georgia State University

To interpret the wide variation in observed chemical abundances during the red giant phase of evolution, it is necessary to develop theoretical and computational modeling of convection under realistic stellar conditions. In this contribution we quantify mixing due to convective penetration in

the deep stellar interior through global hydrodynamic simulations. We produce the evolutionary track of a 3 solar mass red giant using the 1D stellar evolution code MESA. We select models from this evolutionary track at eight different points in time, beginning at the first dredge-up and spanning the brief period of time of the red giant luminosity bump. The realistic stratification in density, temperature, and luminosity of these models is then used to produce global simulations of the stellar interior with the multi-dimensional, time implicit, fully compressible, hydrodynamic, implicit large eddy simulation code MUSIC. We compare the changing amount of mixing using a more sophisticated enhanced diffusion model for convective penetration (Pratt et al 2017), targeted for one-dimensional stellar evolution calculations.

Star formation and disks evolution in clusters: The road to Westerlund 1

Mario Giuseppe Guarcello (1); Facundo Albacete-Colombo (2); Morten Andersen (3); Costanza Argiroffi (4); Liz Bartlett (5); Nate Bastian (6); Cesare Cecchi Pestellini (7); Simon Clark (8); Cathie Clarke (9); Francesco Damiani (10); Jeremy Drake (11); Ettore Flaccomio (12); Adam Ginsburg (13); Joseph Hora (14); Gian Luca Israel (15); Daniele Locci (16); Michela Mapelli (17); Rafael Martinez Galarza (18); Giuseppina Micela (19); Marco Miceli (20); Koraljka Muzic (21); Salvatore Sciortino (22); Andrew Winter (23); Nick Wright (24)

(1) INAF - Osservatorio Astronomico di Palermo; (2) University of Rio Negro, Viedma, Argentina; (3) Gemini Observatory, La Serena, Chile; (4) Università degli Studi di Palermo; (5) Astrophysics, Cosmology and Gravity Centre, Astronomy Department, University of Cape Town, South Africa; (6) Astrophysics Research Institute, Liverpool John Moores University; (7) INAF - Osservatorio Astronomico di Palermo; (8) Open University, Milton Keynes, UK; (9) Institute of Astronomy, University of Cambridge, UK; (10) INAF - Osservatorio Astronomico di Palermo; (11) Harvard-Smithsonian Center for Astrophysics, Cambridge, USA; (12) INAF - Osservatorio Astronomico di Palermo; (13) Department of Astronomy, University of Florida; (14) Harvard-Smithsonian Center for Astrophysics, Cambridge, USA; (15) INAF - Osservatorio Astronomico di Roma; (16) INAF - Osservatorio Astronomico di Palermo; (17) INAF - Osservatorio Astronomico di Padova; (18) Harvard-Smithsonian Center for Astrophysics, Cambridge, USA; (19) INAF - Osservatorio Astronomico di Palermo; (20) Università degli Studi di Palermo; (21) CENTRA, Faculdade de Ciências, Universidade de Lisboa; (22) INAF - Osservatorio Astronomico di Palermo; (23) Astronomisches Rechen-Institut, Zentrum für Astronomie der Universität Heidelberg; (24) Astrophysics Group, Keele University

Stellar clusters younger than $\sim$10 Myrs are natural targets to study star formation, early stellar evolution, and the feedback from the environment on the evolution of protoplanetary disks and planetary formation. Our view of star formation in the Milky Way is typically limited to clusters counting few hundreds to less than few thousands members, and whose mass content is only a small fraction of that of starburst clusters. This is unfortunate because these latter, containing tens of thousands to millions of stars, represent an extreme star forming environment in our Galaxy today, while being common in the early Universe and in starburst galaxies. In our Galaxy only a few starburst clusters are known, with Westerlund$\sim$1 (3–5 Myrs, age spread $<$1 Myr, and an estimated initial total mass of about 52000 $M_{\odot}$) being the closest to the Sun and thus the best laboratory for extending our knowledge on star and planet formation and early stellar evolution to extreme starburst conditions. I will discuss the present-day knowledge about the evolution of protoplanetary disks in clusters and the impact of the environment, and present our multi-wavelength project to study Westerlund$\sim$1, based on a recently accepted Chandra Large Program and both archival and new data.

The SPECULOOS search for rocky planets orbiting ultra-cool dwarfs, and its first discovery

Amaury Triaud; SPECULOOS team

University of Birmingham

SPECULOOS is the Search for Planet Orbiting ULtra-cOOl Stars. It involves a constellation of telescopes in the northern and the southern hemispheres. Their principal activity is to photometrically monitor 1300 objects with spectral type M7 and later, searching for transiting planetary systems, just like we discovered TRAPPIST-1. During my talk I will outline the current status of the project, and describe our first discovery.

While commissioning one of our telescopes in Chile, we noticed an eclipse signal on a nearby brown dwarf visual pair which is part of the 45 Myr Argus group. Follow-up observations obtained at Keck and VLT revealed that the primary is itself a double-line brown dwarf eclipsing binary, the only second known so far. We could measure radii and masses and find them to agree remarkably well with published theoretical expectations. We also noticed that the objects are under-luminous compared to models, which may impact the mass estimates of field brown dwarfs, and directly imaged exoplanets by 20 to 30%.

Constraining Formation Mechanisms of Lithium-Rich Red Giants

Benjamin T. Montet (1); Melissa K. Ness (2)

(1) University of New South Wales; (2) Columbia University

The existence of a population of red giants with high lithium abundance have challenged models of stellar evolution. Several models have been proposed to explain their formation including planetary engulfment, stellar-white dwarf mergers, and tidal effects from wider binary companions, each making different predictions of the rotation rate and binarity of these systems. With large spectroscopic surveys like LAMOST, GALAH, and APOGEE, thousands of these lithium-rich giants have been discovered. Photometric surveys like Kepler, K2, and TESS can be used to measure rotation rates of these stars and make inferences about their binarity. I will present new methodology for measuring slow rotation rates in time series photometry from these missions, which is often removed by the instrument processing pipelines. I will discuss specifically its applications to lithium-rich giants in the Kepler field and in the TESS continuous viewing zone and new resultant constraints on the possible evolutionary pathways of these cool stars.

The X-ray activity-rotation-age relation of M dwarfs

Enza Magaudda (1); Beate Stelzer (2); Kevin R. Covey (3); Sefanie Raetz (4); Sean P. Matt (5); Alexander Scholz (6)

(1) Institut für Astronomie und Astrophysik, Eberhard-Karls Universität Tübingen; (2) INAF-Osservatorio Astronomico di Palermo; (3) Department of Physics & Astronomy, Western Washington University; (4) University of Exeter, Department of Physics & Astronomy; (5) SUPA, School of Physics & Astronomy, University of St Andrews

The activity-rotation relation of M dwarfs provides observational evidence of the stellar dynamo, which is poorly understood for low-mass stars especially in the fully convective regime. Effects of rotational evolution are also encoded in the empirical rotation-activity relation, because stellar rotation slows down throughout a star's main-sequence life. The dynamo efficiency decreases over time causing a decrease of X-ray luminosity ($\mathrm{L_x}$). From past studies it is known that the X-ray activity-rotation relation has a two-regime behavior with saturation for faster rotating stars (i.e. small rotational periods) and with a $\mathrm{L_x}-$decrease for higher $\mathrm{P_{rot}}$. We have performed In this talk I present the most comprehensive and homogeneous study of the X-ray activity-rotation relation of M dwarfs so far, combining new *XMM-Newton* and *Chandra* X-ray observations and *Kepler Two-Wheel* (K2) rotational periods with a systematic assessment and update of literature data. Examining the activity-rotation relation in three different mass bins we find a non-constant X-ray luminosity level in the saturated regime and a mass-dependence of the slope in the unsaturated regime. Exploring the dependence of X-ray activity on the Rossby number, $\mathrm{R_O}$, we identify several interesting features: (1) a remarkable double gap with a paucity of objects at $\mathrm{L_x/L_{bol}} \sim 10^{-4}$, that might be interpreted as a phase of stalled rotational evolution followed by an episode of rapid spin-down, and (2) different slopes in the unsaturated regime for different parametrizations of the Rossby number. Combining our best fit parameters from the $\mathrm{L_x} - \mathrm{P_{rot}}$ analysis with spin-down models we constructed the first $\mathrm{L_x}-$age relation for M dwarfs and we compared it to the activity of M stars with known age. Finally I present first results from an extension of our work to all-sky data from the *eROSITA* X-ray mission combined with new rotation periods from *TESS*.

Rapid Spectroscopic Classification of Keck HIRES Stars with The Cannon

Malena Rice (1); John Brewer (2); Debra Fischer (3)

(1) Yale University; (2) San Francisco State University; (3) Yale University

Accurate spectroscopic properties of stars are of critical importance to rigorously examine the relationship between host stellar environment and exoplanetary system properties. However, many tools designed to extract these properties require extensive computation time that can be inhibitive for large samples. To address this problem, we devise a new scheme that rapidly recovers stellar properties from input Keck HIRES spectra by combining The Cannon, which uses supervised learning to extract stellar labels, with the Spectroscopic Properties of Cool Stars (SPOCS) catalog of over 1000 stars previously analyzed with the Spectroscopy Made Easy (SME). We demonstrate that our model recovers 18 labels — logg, Teff, vsini, and 15 elemental abundances (C, N, O, Na, Mg, Al, Si, Ca, Ti, V, Cr, Mn, Fe, Ni, and Y) with remarkable accuracy, including uncertainties roughly equivalent to the discrepancy between different spectroscopic catalogues. Finally, we demonstrate that, by interpolating our input spectra to a separate but overlapping wavelength range, we accurately recover stellar labels for archival Keck HIRES spectra, observed prior to the 2004 detector upgrade, that could not be analyzed uniformly together with the SPOCS catalog due to their more limited wavelength coverage. We conclude with prospects for applying this technique to spectra obtained using different spectrographs – a promising, potentially generalizable method for rapid spectroscopic classification.

The Effects of Convective Assumptions on Fundamental Stellar Parameters

Meridith Joyce (1); Martin Asplund (2); Tim R. White (3); Thomas Nordlander (4)

(1) Australian National University; (2) Australian National University; (3) University of Sydney; (4) Australian National University

In 1D stellar structure and evolution programs, the 60-year-old Mixing Length Theory (MLT) formalism is used to model energy transport in the sub-surface convection zones of low-mass and solar-like stars. Despite mounting evidence that the practice leads to considerable inaccuracies in fundamental stellar parameter determinations, the method of calibrating the convective mean-free path, or α_{MLT}, to the Sun and adopting this value ad hoc in non-solar models runs rampant in computational stellar astrophysics.

The work of Joyce et al. (2018a) and (2018b) has demonstrated that reliance on a solar-calibrated α_{MLT} is highly inadequate in models generated with the Dartmouth Stellar Evolution Program (DSEP), leading to misestimations of temperatures by several hundred Kelvin and stellar ages by 0.5–1 Gyr. My work since has found similar results in models generated with the MESA (Modules for Experiments in Stellar Astrophysics) program and likewise revealed the mixing length's sensitivity to assumptions about solar abundances and the opacities tailored to them.

These results call into question the use of current stellar evolution databases—all of which assume solar-calibrated mixing lengths in their isochrones—and advance the urgency of generating better models. This has inspired the initiatve to compute a library of precision estimates for the mixing length using a range of physical prescriptions in MESA.

Asteroseismic binaries, especially those systems comprising solar analogs, are ideal candidates for empirical mixing length calibrations. These calculations, however, require tight constraints from many diverse observational inference methods and thus rely on high precision observations in many arenas: classical brightness measurements, interferometry, spectroscopy, and asteroseismology. In light of unprecedented observational scope and precision—thanks to Gaia, TESS, and stable, high resolution spectroscopy—the number of candidates for non-solar calibration is increasing. In this talk, I will discuss promising results from mixing length calibrations from select candidates and the significance of these results for isochrones and other stellar models.

The loci of megaflares on the surfaces of fully convective stars

Ekaterina Ilin (1); Sarah J. Schmidt (2); Katja Poppenhäger (3); Silva Järvinen (4); Ilya Ilyin (5); Mahmoud Oshagh (6)

(1) Leibniz Institute for Astrophysics Potsdam (AIP); (2) Leibniz Institute for Astrophysics Potsdam (AIP); (3) Leibniz Institute for Astrophysics Potsdam (AIP); (4) Leibniz Institute for Astrophysics Potsdam (AIP); (5) Leibniz Institute for Astrophysics Potsdam (AIP); (6) Instituto de Astrofisica de Canarias

Small, fully convective stars produce intense white light flares that indicate strong stellar magnetic fields. However, how these fields are produced is still unclear, since the solar-like magnetic dynamo requires a star to have a radiative core which is missing in these stars, and alternative dynamo models still struggle with reproducing the observables of fully convective stars. Using Kepler and TESS light curves, we discovered long-duration flares on fully convective, fast rotating (P<12h) stars. These flares last for several stellar rotation periods so that their loci repeatedly move in and out of view. The observed light curves are distinctly modulated and provide the unique possibility to infer the latitudes where the flares occurred. We demonstrate that the observed flare light curves can be adequately described by rotational modulation of bright (10 000 K) photospheric spots. In some cases, the degeneracy with rotational inclination can be broken by combining measurements of rotational line broadening with the photometric rotation period. For these stars, we inferred the latitudes of the spots, and the flares' properties. The results provide important constraints for dynamo models of fully convective stars.

The magnetic obliquity of accreting T Tauri stars

Pauline McGinnis (1); Jérôme Bouvier (2); Florian Gallet (3)

(1) Dublin Institute for Advanced Studies; (2) Institut de Planétologie et d'Astrophysique de Grenoble

Classical T Tauri stars (CTTS) accrete material from their disk through their magnetosphere. The geometry of the accretion flow strongly depends on the magnetic obliquity, i.e., the angle between the rotational and magnetic axes. In this work, we derive the distribution of magnetic obliquities in a sample of 11 accreting T Tauri stars, by monitoring the radial velocity variations of the HeIλ5876 line in their spectra along their rotational cycle. He~I is produced in the accretion shock, close to the magnetic pole. When the magnetic and rotational axes are not aligned, the radial velocity of this line is modulated by stellar rotation, with an amplitude that is related to the star's projected rotational velocity ($v \sin i$) and the latitude of the hotspot. By deriving $v \sin i$ and He~I radial velocity curves from our spectra we thus obtain an estimate of the magnetic obliquities. In our sample, we find an average obliquity of 11.4°, with an rms dispersion of 5.4°. The magnetic axis thus seems nearly but not exactly aligned with the rotational axis in these stars, somewhat in disagreement with studies of spectropolarimetry, which have found a significant misalignment ($\gtrsim 20°$) for several CTTS. This difference compared to previous studies could simply be an effect of low number statistics, or it may be due to a selection bias of our sample. From their positions on the HR diagram, we note that most of the stars in our sample should still be fully convective. We find tentative evidence that the magnetic obliquity may vary according to the stellar interior and that there may be a significant difference between fully convective and partly radiative stars. We also find that the star IW~Tau, which is classified as a weak-line T Tauri star, shows evidence of ongoing accretion at a reduced rate, and discuss the possibility of differential rotation in the accretion columns of T~Tau.

Investigating episodic accretion in very low-mass young stellar objects

Camille Stock (1); Alessio Caratti o Garatti (2); Pauline McGinnis (3); Rebeca Garcia-Lopez (4); Tom P Ray (5)

(1) Trinity College Dublin & Dublin Institute for Advanced Studies; (2) Dublin Institute for Advanced Studies; (3) Dublin Institute for Advanced Studies; (4) Dublin Institute for Advanced Studies; (5) Dublin Institute for Advanced Studies

Very low-mass Class I protostars have been studied very little thus far. Variability of these YSOs and whether they are capable of strong, violent bursts in accretion activity is also left relatively unstudied. We investigate these processes and variability of IRS54, a Class I very low-mass protostar with a mass of $M_{\star} \sim 0.1 - 0.2 M_{\odot}$. Spectroscopic and photometric data were obtained with VLT/ISAAC and VLT/SINFONI in the near-infrared (J, H and K-bands) across four epochs (2005, 2010, 2013 and 2014) to study IRS54 for any observed variabilities. Accretion-tracing lines ($Pa\beta$ and $Br\gamma$) and outflow-tracing lines (H_2 and [FeII]) are used to study physical properties and kinematics of the object. Through continuum-subtracted emission maps of H_2 and [FeII], the molecular and atomic emission from the jet has been found to be asymmetric, with the H_2 mostly red shifted and the [FeII] mostly blue shifted. This agrees with predictions found in the literature. A large increase in luminosity was found between the 2005 and 2013 epochs, of over 2 mag in the K-band, then in 2014 there was a steep decrease. Also increasing between 2005 and 2013 was the mass accretion rate ($\dot{M}_{acc}$), which increased by an order of magnitude from $\sim 10^{-8} M_{\odot} yr^{-1}$ to $\sim 10^{-7} M_{\odot} yr^{-1}$. The visual extinction (A_V) has increased from ~ 15 mag in 2005 to ~ 24 mag in 2013. This increase in A_V in tandem with the increase in $\dot{M}_{acc}$ is explained by the lifting up of a large amount of dust

from the disk, due to the violent accretion and ejection activity in the YSO. Due to the strength and timescales involved in this dramatic increase, this event is believed to have been an accretion burst similar to EXor bursts. This makes IRS54 the lowest mass Class I source to have an accretion burst of this significance observed, and could potentially be an EXor-type object.

Simulating the Deep Origins of M-Dwarf Super-Flares

Connor P. Bice (1); Juri Toomre (2)

(1) JILA / University of Colorado Boulder; (2) JILA / University of Colorado Boulder

We present the results of global 3D MHD simulations of the convective interiors and tachoclines of $0.4M_\odot$ M-dwarf stars, exploring the origins of their fierce magnetic activity. Our dynamo simulations reveal peak field strengths greater than 50 kG, as well as self-consistent, buoyantly rising flux ropes triggering a precursor event for our modeled star to begin producing flares with total energy content in excess of 10^{37} ergs. From this, we identify one possible mechanism by which such stars may be able to power their super-flares. We also introduce testable predictions for the evolution of global magnetic field topology on super-flare stars consistent with our proposed energy source.

Modeling Luminosity-Activity Relations in Unsaturated Cool Stars

Alison Farrish (1); David Alexander (2); Christopher Johns-Krull (3); Minjing Li (4)

(1) Rice University; (2) Rice University; (3) Rice University; (4) University of Science and Technology of China

We investigate whether cyclic variations in stellar activity can account for the observed spread in fractional X-ray luminosity, L_X/L_{bol}, for cool stars in the unsaturated range of Rossby number, $Ro \gtrsim 0.1$. To address this question, we employ an empirical flux transport model of the stellar surface, incorporating modulations of magnetic flux strength consistent with observed stellar activity cycles. We find that for stellar flux models corresponding to a range $\sim 0.1 \lesssim Ro \lesssim 2$, the L_X/L_{bol} vs. Ro relation matches well the power-law behavior observed in the “unsaturated" regime of cool stars. Additionally, the magnetic activity cycles incorporated into the stellar simulations produce a spread about the power-law relation consistent with the observed spread in unsaturated cool star populations. We find, therefore, that the solar-based flux transport approach employed in this work can reproduce the X-ray luminosity-magnetic activity relation observed across the range of unsaturated G, K, and M stars, providing support for the hypothesis of a universal connection between photospheric flux and coronal X-rays operating in all unsaturated cool stars. We further conclude that the spread in fractional X-ray luminosity, L_X/L_{bol}, across the unsaturated range of stellar activity corresponding to $\sim 0.1 \lesssim Ro \lesssim 2$ can be explained by the intrinsic variation due to stellar activity cycles.

The Influence of sun-like magnetic cycle on exoplanetary atmospheric escape

Gopal Hazra; Aline Vidotto; Carolina Villarreal D’Angelo

Trinity College Dublin

Radiation from host stars (e.g., X-ray and UV) is one of the main source of driving exoplanetary wind and affecting exoplanetary atmospheric escape. Given that the stellar irradiation depends on the stellar magnetic field and stars have magnetic cycle, we investigate the cyclic evolution of exoplanetary atmospheric escape. We use the solar Extreme UV (EUV) data which is strongly correlated with 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 1D hydrodynamic escape model. This 1D hydrodynamic escape model is widely used to study the physical properties of exoplanetary atmosphere and their mass loss rate. We find that 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 Ly-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 HD189733 from Zeeman Doppler Imaging (ZDI) technique to get EUV fluxes and study the atmospheric escape from those exoplanetary system to compare the results with available spectroscopic transit observations.

HAZMAT's Spectroscopic Perspective on the Ultraviolet Lives of Early M Stars

Evgenya Shkolnik (1); Adam Schneider (2); Tyler Richey-Yowell (3); Travis Barman (4); Sarah Peacock (5); Isabella Pagano (6); Victoria Meadows (7)

(1) Arizona State University; (2) Arizona State University; (3) Arizona State University; (4) University of Arizona; (5) University of Arizona; (6) Osservatorio Astrofisico di Catania; (7) University of Washington

Exoplanets orbiting in the habitable zones of M stars are subject to a radiation environment much different than the Sun's. In this environment, ultraviolet radiation that ionizes, dissociates, heats, and erodes planetary atmospheres is more intense. Moreover, this radiation is subject to frequent spikes in the form of stellar flares. The levels of this radiation, both quiescent and flaring, evolve as stars age. Recently, the HAbitable Zones and M dwarfs Activity across Time (HAZMAT) program carried out a spectroscopic survey of M0-M2 stars at ages of 40 Myr, 650 Myr, and several Gyr using HST's Cosmic Origins Spectrograph (COS). In this talk, we present the evolution of M star ultraviolet spectra from 40 Myr to several Gyr. We examine the spectroscopic similarities after correcting for differences in radius and rotation, exploring how well a single spectrum could describe all stars of the same age and mass. Taking advantage of COS's photon counting capability, we also measure the change in flare rates of early M stars as they, pointing out a parallel between emission line responses to a flare and changes in quiescent line strengths with age. We highlight one flare, likely representing a daily event on young M stars, that included substantial 15,500 K pseudo-continuum emission. This work lays the foundation for studies of the physical evolution of both the stellar and planetary atmospheres in early M star systems throughout their lives.

The Influence of Age and Mass on Ultracool Dwarf and Brown Dwarf Magnetism

Melodie Kao; Evgenya Shkolnik

Arizona State University

In the last decade, radio aurorae on ultracool dwarfs (>M7) yielded insights into the magnetic dynamos operating in objects that bridge the gap from stars to planets. Statistical studies of magnetic

activity from young, lower-mass brown dwarfs, which remain hot from their recent formation, provide a new opportunity to assess how excess heat and mass influence ultracool dwarf, brown dwarf, and exoplanet dynamos. We have observed 20 young brown dwarfs with spectral types between M7.5 - T5.5 using the Karl G. Jansky Very Large Array (VLA) from 4-8 GHz, doubling the number of young brown dwarfs that have been observed at radio frequencies. We search for the presence of non-bursting radio emission as a tracer of magnetism to investigate the significance of youth in the radio activity of ultracool dwarfs and brown dwarfs. We report a new radio detection of a young brown dwarf. We combine the results of our survey with previous radio observations reported in the literature to present the first statistical study of radio activity on young brown dwarfs, and what this teaches us about the influence of age and mass on ultracool dwarf and brown dwarf magnetic activity.

Starspots and Magnetism in Young Stars

Christian Flores; Michael Connelley; Bo Reipurth

Institute for Astronomy, University of Hawaii at Manoa, 640 N. Aohoku Place, Hilo, HI 96720, USA

Starspots are byproducts of surface magnetism in stars with convective envelopes, and young stars are known to have ∼kG magnetic fields on their surfaces. From these two facts, it is expected that a significant fraction of the surface of young stars is covered by dark spots. The observational complications induced by starspots are that effective temperature measurements, especially if determined using optical observations, could be biased toward hotter values.

To investigate this effect in young stars, we present an ongoing K-band spectroscopic survey of ∼50 CTTS in Taurus and Ophiuchus using the high-resolution NIR spectrograph iSHELL. We have modeled the spectra of the stars using a magnetic radiative transfer code and we have derived their stellar parameters. Here we present a comparison between our derived K-band temperatures and literature optical temperature measurements. We also investigate the role of magnetic fields by correlating our derived magnetic field strengths with optical vs. NIR temperature differences, surface gravity values, and other stellar parameters. Finally, we use our derived stellar properties along with ALMA dynamical stellar masses to test state-of-the-art stellar evolutionary models.

Precise and accurate parameters of spotted stars in eclipsing binaries

Krzysztof G. Hełminiak (1); Andres Jordan (2); Nestor Espinoza (3); Rafael Brahm (4); Nobuharu Ukita (5); Eiji Kambe (6); Hiroyuki Maehara (7); Milena Ratajczak (8); Maciej Konacki (9); Piotr Sybilski (10); Frederic Marcadon (11); Rafał Pawłaszek (12)

(1) N. Copernicus Astronomical Center Toruń; (2) Facultad de Ingenieria y Ciencias, Universidad Adolfo Ibanez & Millenium Institute of Astrophysics; (3) Space Telescope Science Institute; (4) Facultad de Ingenieria y Ciencias, Universidad Adolfo Ibanez & Millenium Institute of Astrophysics; (5) Okayama Astrophysical Observatory NAOJ & The Graduate University for Advanced Studies; (6) Subaru Telescope NAOJ; (7) The Graduate University for Advanced Studies; (8) Warsaw University Astronomical Observatory; (9) N. Copernicus Astronomical Center Warsaw; (10) N. Copernicus Astronomical Center Toruń; (11) N. Copernicus Astronomical Center Toruń; (12) N. Copernicus Astronomical Center Toruń

Since 2011 we have been conducting an extensive spectroscopic survey of detached eclipsing binaries (DEBs), and obtaining precise radial velocity (RV) data for hundreds of DEBs, including

many with highly active, cool (G,K,M-type dwarf and giant) components. We also gathered high-quality time series photometry from Kepler/K2 and TESS satellite missions, which often shows large stellar spots, that additionally evolve rapidly, in time scales comparable to orbital periods of the DEBs.Thanks to the superb data sets we were able to properly take the spot-originated modulations into account, and obtain absolute masses, radii and other stellar parameters with a very high relative precision of 0.2-2%. For DEBs already described in the literature, our results are several times more precise than previously reported.

Flux Emergence/Decay on Stellar Surfaces Revealed by Kepler Data

Kosuke Namekata (1), Hiroyuki Maehara (2), James Davenport (3), Brett Morris (4), Suzanne Hawley (3), Yuta Notsu (5, 6), Shin Toriumi (7), Hisashi Hayakawa (8), Shota Notsu (9), Kai Ikuta (1), Satoshi Honda (10), Daisaku Nogami (1), Kazunari Shibata (1)

(1) Kyoto Univ., (2) NAOJ, (3) Univ. of Washington, (4) Univ. of Bern (5) LASP, Univ. of Colorado Boulder, (6) NSO, (7) JAXA, (8) Osaka Univ., (9) RIKEN, (10) Univ. of Hyogo

Active solar-type stars show large quasi-periodic brightness variations caused by large star spots. The temporal evolution of individual star spots is important for understandings of the stellar dynamo and the occurrence condition of stellar flares although it has not been well studied, especially for solar-type stars. Recent long-term photometric observations by Kepler Space Telescope enable us to investigate the emergence/decay processes of star spots. In this talk, we report measurements of temporal evolution of star-spot area on solar-type stars based on Kepler data and comparisons with sunspot properties. We estimated the statistical values of spot areas, lifetimes, and emergence/decay rates of star spots by modeling rotational brightness modulations (Namekata et al. 2019) and the small brightness variation during exoplanet transit (Namekata et al. 2020). As a result, overall lifetimes of star spots are ranging from 10 to 350 days when spot areas are 0.1-2.3% of a stellar hemisphere. This indicates that, once large star spots appear, the magnetic activity like stellar flares/coronal mass ejections can threaten the exoplanet habitability for such a long period. Also, we found that the emergence/decay rates of the large star spots are typically 5×10^{20} Mx/h and are mostly consistent with those expected from sunspots observations (Petrovay et al. 1997, Norton et al. 2017). This supports that the flux emergence/decay of extremely large star spots (0.1-2.3% of SH) can share the same process with that of relatively small sunspots ($<$ 0.5% of SH). We also present possible future studies with space-based telescope (e.g. TESS), ground-based spectroscopy (e.g. DI/ZDI), and numerical simulations (e.g. Hotta 2019).

PEPSIpol view of EK Draconis

S. P. Järvinen; T. A. Carroll; K. G. Strassmeier; I. V. Ilyin

Leibniz Institute for Astrophysics Potsdam (AIP)

It is known that Stokes V profiles can be fitted equally well by very different magnetic field topologies. Unfortunately, there has been hardly any observations of cool stars in full Stokes parameters, but nevertheless the results imply that using Stokes IVQU increases the complexity of the field topology and reveal small scale features.

EK Draconis is one of the well studied analogues of the young Sun. The surface spot distribution has been mapped for several epochs and additionally four epochs have also the magnetic field topology based on Stokes IV. The major features in already published magnetic field maps are an almost unipolar azimuthal field and rather weak meridional field. This could imply that this is part of

the preferred magnetic field configuration in these types of stars. However, more likely explanation is the use of only Stokes V component.

We present the results based on the spectropolarimetric observations (R=130000) of EK Dra obtained with the Potsdam Echelle Polarimetric and Spectroscopic Instrument (PEPSI) at the Large Binocular Telescope (LBT) in May 2019. The full Stokes parameters were obtained and the stellar surface is reconstructed using the iMAP code.

UV chemistry in the outflows of AGB stars

Maryam Saberi (1); Wouter Vlemmings (2); Hans Olofsson (3); Elvire De Beck (4)

(1) Rosseland Centre for Solar Physics, University of Oslo; (2) Chalmers University of Technology

Low- and intermediate-mass stars eject a substantial amount of their material into space during a late phase of stellar evolution, the asymptotic giant branch (AGB) phase. Due to the intense mass loss, a circumstellar envelope (CSE), rich in gas and dust, forms around the AGB star. Observations of molecular species and dust content in CSEs help us to broaden our knowledge on late phases of stellar evolution, mass-loss processes, the CSE chemistry, and the stellar properties.

It is well known that UV radiation impacts the CSE chemistry through molecular photodissociation. The potential sources of UV radiation that can impact the CSE chemistry are the interstellar radiation field (ISRF), stellar chromospheric activity, and hot binary companions.

Comparing the isotopologue ratio of species with different photodissociation paths is a new way to quantify the impact of UV chemistry in CSEs. In this talk, I will present our results of chemical and radiative transfer analysis of CO and HCN isotopologue ratios in the CSEs of both carbon- and oxygen-rich AGB stars.

The curious case of Betelgeuse

Thomas Granzer (1); Klaus G. Strassmeier (2); Rainer Kuschnig (3); Gregg Wade for the BRITE team (4)

(1) Leibniz Institute for Astrophysics, Potsdam; (2) Leibniz Institute for Astrophysics, Potsdam; (3) University of Technology, Graz; (4) Queen's Universit, Kingston, CA

Since more than a decade, the AIP is monitoring α Ori with its robotic spectroscopic facility STELLA/SES in Teide observatory, Tenerife and with its automated photoelectric telescope T7 in Fairborn observatory, Az. Additionally, we were awarded with exclusive two-band photometric data on Betelgeuse from the BRITE satellite consortium, covering the last seven seasons. In late 2019, Betelgeuse showed a rapid brightness decline, reaching an all-time low in Feb. 2020, which just now (beginning of March) seems to halt and may even reverse.

In this talk, I want to present photometric and radial-velocity data along with some preliminary interpretation.

Unbiased Effective Temperatures of Red Supergiants from Iron Absorption Lines

Daisuke Taniguchi (1); Noriyuki Matsunaga (2); Mingjie Jian (3); Naoto Kobayashi (4); Kei Fukue (5); Satoshi Hamano (6); Yuji Ikeda (7); Hideyo Kawakita (8); Sohei Kondo (9); Hiroaki Sameshima (10); Chikako Yasui (11)

(1) The University of Tokyo; (2) The University of Tokyo; (3) The University of Tokyo; (4) The University of Tokyo; (5) Kyoto Sangyo University; (6) National Astronomical Observatory of Japan; (7) Photocoding & Kyoto Sangyo University; (8) Kyoto Sangyo University; (9) The University of Tokyo; (10) The University of Tokyo; (11) National Astronomical Observatory of Japan

Observational determination of the effective temperatures of red supergiants (RSGs) is important in many aspects of stellar physics and galactic astronomy, e.g., testing stellar evolution models and measuring chemical abundances. Among spectroscopic approaches to determining the temperatures, the methods making use of atomic lines in high-resolution spectra has some advantages compared to those using molecular bands; relatively shallow atomic lines are less affected by the uncertain temperature structure in the upper atmosphere of RSGs. A promising approach is the line-depth ratio (LDR) method using ratios of line depths of two atomic absorption lines, which has been successfully applied to various kinds of late-type stars (e.g. Gray & Johnson 1991, Taniguchi et al. 2018). In this work, we established the relations between effective temperature and LDR of two neutral Fe lines based on calibrating red giants. Our LDR indicators are expected to give temperatures consistent for both red giants and RSGs because the LDR of two neutral Fe lines are insensitive to the surface gravity. We then determined the effective temperatures of six nearby RSGs observed with the WINERED spectrograph (near-infrared YJ bands) to a precision of $\sim$40K. The resultant effective temperatures show good agreement with the Geneva's stellar evolution model.

Explosive nucleosynthesis as the source of a distinct odd-even effect in the solar twin HIP 11915

Jhon Yana Galarza (1); Jorge Meléndez (2); Diego Lorenzo-Oliveira (3); Amanda I. Karakas (4); Martin Asplund (5); Lorenzo Spina (6); Fan Liu (7)

(1) Universidade de São Paulo; (2) Universidade de São Paulo; (3) Universidade de São Paulo; (4) Monash University; (5) The Australian National University; (6) Monash University; (7) Lund University

The odd-even effect is clearly observed in the Sun and metal-poor stars. An important question is whether the odd-even effect in solar-metallicity stars is similar to the Sun, or if there are variations that can tell us about different enrichment histories by supernova. In this work, we report for the first time evidence of the odd-even effect in the solar twin HIP 11915. The spectra of this star were obtained with high resolving power (140 000) and signal-to-noise ratio ($\sim$420) using the ESPRESSO spectrograph and the VLT telescope. Thanks to this precision, we obtained extremely precise stellar parameters ($\sigma(T_{\rm eff})$ = 4 K, $\sigma([\rm Fe/H])$ = 0.005 dex, and $\sigma(\log g)$ = 0.008 dex). We also determined the abundance of 18 light elements ($Z \leq 30$), which shows a clear pattern of the odd-even effect, whose dispersion is much bigger than their abundance uncertainties ($\sim$0.01 dex). Our results indicate that HIP 11915 has an odd-even effect somewhat different than the Sun, pointing out for a somewhat different supernova enrichment history.

The Dynamo-Wind Feedback Loop: Characterizing how the solar wind varies along a dynamo cycle

Allan Sacha Brun (1); Antoine Strugarek (2); Victor Réville (3)

(1) CEA/AIM; (2) CEA/AIM; (3) CNRS/IRAP

Though generated deep inside the convection zone, the solar magnetic field has a direct impact on the Earth space environment via various mechanisms. In particular, it strongly modulates the

solar wind in the whole heliosphere: observations have shown that the 11-year cycle created by the dynamo inside the Sun affects the latitudinal speed distribution of the solar wind over the years. However, the wind also influences the topology of the coronal magnetic field by opening the magnetic field lines in the coronal holes, which can affect the inner magnetic field of the star by altering the dynamo boundary conditions. This coupling is especially difficult to model because it covers a large variety of spatio-temporal scales. Quasi-static studies have begun to help us unveil this how the dynamical dynamo magnetic field shapes the wind. Nevertheless, the full interplay between the solar dynamo and the solar wind still eludes our understanding. We use the compressible magnetohydrodynamical code PLUTO to compute simultaneously in 2.5D the generation and evolution of magnetic field inside the star via an alpha-omega dynamo process and the corresponding evolution of the corona over a dynamo cycle. A multi-layered internal boundary condition at the surface of the star connects the inner and outer stellar layers, allowing both to adapt and update in real time. We focus on young suns to test the parameter range in which the coupling is effective, with dynamo cycle periods between 5 weeks and 5 days. Our coupled dynamo-wind model allows us to characterize how the solar wind conditions change as a function of the cycle phase, and also to quantify the evolution of the Alfvén surface, mass and angular momentum losses with the changing dynamo field. We further assess for the first time the impact of the solar wind on the dynamo itself by testing different levels of feedback and comparing them to no feedback at all. Finally, we characterize the exchange of information between inner and outer stellar layers in terms of helicity. This gives us a new tool to better understand the Sun-Earth connection at various moments of the solar cycle in a space weather perspective and to eventually extend it to other stars with different rotation and level of activity.

Moving beyond stellar activity limitations to detect other Earths: radial velocities and high-precision astrometry

Nadège Meunier (1); Anne-Marie Lagrange (2); Simon Borgniet (3); Thibault Boulet (4); Sylvain Cuzacq (5)

(1) Univ. Grenoble Alpes, CNRS, IPAG, F-38000 Grenoble, France; (2) Univ. Grenoble Alpes, CNRS, IPAG, F-38000 Grenoble, France; (3) LESIA, Observatoire de Paris, Université PSL, CNRS, Sorbonne Université, Université de Paris, 5 Place Jules Janssen, 92195Meudon, France; (4) Instituto de Astrofisica e Ciencias do Espaço, Universidade do Porto, Rua das Estrelas, 4150-762 Porto, Portugal; (5) Univ. Grenoble Alpes, CNRS, IPAG, F-38000 Grenoble, France

Stellar variability strongly affects radial velocity measurements and therefore limits the detectability and mass characterization of low mass planets with this technique. I will present the challenges due to magnetic activity and photospheric flows at different temporal and spatial scales. I will focus on our recent results showing that flows such as supergranulation and meridional circulation significantly affect integrated radial velocities measurements as well, and point out the need for better knowledge of these stellar processes. I will show how our simulations of realistic stellar time series of observables taking these processes into account allowed us to understand better some limitations, allowing to improve mitigating methods, and to estimate the performance to detect Earth-like planet in the habitable zone. We have also been able to compare performance between radial velocity and high precision astrometry techniques.

The innermost regions of protoplanetary disks seen by GRAVITY at VLTI

Karine Perraut for the GRAVITY Collaboration

CNRS/IPAG

Recent advances in star and planet formation studies have been achieved thanks to observations at high-angular resolution in the last few years. In particular, near-infrared (NIR) interferometry probes the inner disk on sub-au scales, allowing to study star-disk interactions, and allows to constrain accretion/ejection phenomena when coupled with spectral resolution. In this contribution, I will show how the GRAVITY instrument installed at the combined focus of the VLTI interferometric array brings unprecedented details on the complex innermost regions of planet-forming disks. I will report on the NIR continuum emission study of 27 Herbig stars, the first critical tests of magnetospheric accretion scenario in young suns, the resolution of CO bandhead emission at sub-au scales. In addition, GRAVITY has provided outstanding, high-quality atmospheric spectra of two young hot Jupiter exoplanets, ten times better than previous coronographic integral field spectroscopy. Finally, prospects with the future GRAVITY+ instrument will also be discussed.

On the fate of an engulfed brown dwarf as a red giant companion

Rafeel Riaz (1); Lombardi, James C. Jr. (2); Dominik R.G. Schleicher (3)

(1) Departamento de Astronomía, Facultad Ciencias Físicas y Matemáticas, Universidad de Concepción, Av. Esteban Iturra s/n Barrio; (2) Universitario, Casilla 160-C, Concepción, Chile; (3) Department of Physics, Allegheny College, Meadville, PA 16335, USA; (4) Departamento de Astronomía, Facultad Ciencias Físicas y Matemáticas, Universidad de Concepción, Av. Esteban Iturra s/n Barrio.

We report simulation results of a red giant-brown dwarf (RG$-$BD) binary system in which the brown dwarf evolves within the envelope of a red giant. We consider brown dwarfs of 0.053 $M_\odot$ and 0.075 $M_\odot$, and we use an ideal gas equation of state (EOS) with the radiation pressure. Along with the two distinct masses of brown dwarf, we explore the scenario with various red giant masses (0.803, 0.904, 0.953 $M_\odot$) and sizes of the associated envelope (25, 50, 100 $R_\odot$). Our findings suggest that binary systems in which the brown dwarf orbits the red giant at relatively small initial binary separation of 25 $R_\odot$ exhibits significant mass variations during the dynamical evolution of the system. A sharp increase in mass gain of the brown dwarf followed by a mass loss remains inevitable regardless of the initial mass of the brown dwarf. The dynamical evolution also causes the brown dwarf to experience a sudden rise in density which may even cause hydrogen flash when the BD is crushed around the RG core during its inspiral phase. A similar trend for the evolution of the brown dwarf is also observed for binary systems with initial binary separation of 50 $R_\odot$. However, a sharp density increase remains the feature of a less massive brown dwarf. It is expected that the turbulent flows of sufficient density that collide with ram pressure can produce a shock-compressed layer. This subsequently can facilitate the brown dwarf to condense and acquire high core density. Brown dwarfs with binary separation of 100 $R_\odot$ also exhibit mass gain, but due to slow dynamical evolution, the net mass gain remains relatively low. Our preliminary results strongly suggest that a sophisticated equation of state and possibly a nucleosynthesis treatment would be important to model the evolution of such RG$-$BD binary systems.

Rotation measurements for Eclipsing Binaries

A. C. Mattiuci F., L. de Almeida, J. Bouvier, M Deleuil (1); J.-D. do Nascimento Jr. (2)

(1) Departamento de Física, Universidade Federal do Rio Grande do Norte, 59072-970 Natal, RN, Brazil; (2) Harvard-Smithsonian Center for Astrophysics, Cambridge, MA 02138, USA; (3)

Université Grenoble Alpes, CNRS, IPAG, 38000 Grenoble, France; (4) Aix-Marseille Université, CNRS, CNES, LAM (Laboratoired'Astrophysique de Marseille) UMR 7326, 13388 Marseille, France

Space mission like CoRoT, KEPLER and TESS are designed and launched specifically to find Earth-sized planets orbiting nearby stars. The large field of view features from these satellites allow to observe continuously with high-precision instrumental level a large sample of single stars, as well as eclipsing binary stars. Eclipsing binary systems (EBs) are a small fraction of all the multiple systems. They are fundamental for determining stellar parameters and linked to spectroscopically derived parameters allow us to determine component masses. By observing the orbit of those systems, we can better constrain the physics from theoretical models. In addition, the binary orbit may shift in a regular way ('apsidal motion') causing variation of the eclipse depth and revealing about the internal mass distribution of the stars. Even if some studies of EBs are focused on the discovery and analysis of the system, only a few are devoted to measure and interpret the rotation rates of these stars. Thus, in this study, we cross-related eclipsing binaries from CoRoT, KEPER and TESS missions with Gaia DR2, and we set up a sample, as big as possible, of binary system within spectral types G and K, and orbiting dwarfs and more evolved stars. Specifically, for the CoRoT mission (our focus now), we present a final sample composed by 144 systems with orbital period and eccentricity already known in the literature. For those stars, by using binary star (ELLC) modeling from Maxted (2016), we confirmed eccentricities for 27 systems. We determined rotational period for 72 systems by using the DRUM TONNES algorithm (de Almeida et al. 2020) which identifies and eliminates transits from the light curve and recover residual rotational modulation. For 3 of them we present here high resolution spectroscopy observations obtained with Gemini Remote Access to CFHT ESPaDOnS Spectrograph (GRACES). Our aim is to measure the rotational periods for a very precise set of eclipsing binaries and analyze the relationship with the orbital period and eccentricity. From these observations we obtained characteristics about mass, synchronization and circularization of the systems, and we discuss pseudo-synchronization, differential rotation and circularization times for those systems. Finally, we conclude by describing prospects of our project and how we will apply our methodology to a database composed by eclipsing binaries observed by the Kepler and TESS satellites.

Eruptive events in active stars: Lessons from numerical simulations

Julián D. Alvarado-Gómez (1); Jeremy J. Drake (2); Federico Fraschetti (3); Cecilia Garraffo (4); Ofer Cohen (5); Sofia P. Moschou (6); Christian Vocks (7); Katja Poppenhäger (8); Rakesh K. Yadav (9); Ward B. Manchester IV (10)

(1) Leibniz Institute for Astrophysics Potsdam; (2) Center for Astrophysics | Harvard & Smithsonian; (3) University of Arizona; (4) Harvard University; (5) University of Massachusetts at Lowell; (6) Center for Astrophysics | Harvard & Smithsonian; (7) Leibniz Institute for Astrophysics Potsdam; (8) Leibniz Institute for Astrophysics Potsdam; (9) Harvard University; (10) University of Michigan

Flares and coronal mass ejections (CMEs) are more energetic than any other class of solar phenomena. These events involve the rapid release of up to 10^{33} 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 evolution of activity and rotation, as well as the environmental conditions around low-mass stars. 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. In this talk, I will review recent results obtained from realistic modeling of CMEs in active stars. Emphasis will be given to M dwarfs, focusing on possible observable coronal signatures of these events using

next-generation X-ray missions. Furthermore, an explanation for the lack of Type II radio bursts from CMEs in active M dwarfs despite their frequent flaring will be discussed. Finally, the implications and relevance of these numerical results will be considered in the context of future characterization of host star-exoplanet systems.

The Origin of p-mode Asymmetry and Asymmetry Reversal in Solar-like Oscillators

J. Philidet (1); K. Belkacem (2); R. Samadi (3); C. Barban (4); H.-G. Ludwig (5)

(1) Observatoire de Paris; (2) CNRS/Observatoire de Paris; (3) CNRS/Observatoire de Paris; (4) CNRS/Observatoire de Paris; (5) Universität Heidelberg & Observatoire de Paris

Space-borne missions such as CoRoT or Kepler allow us to achieve a spectral resolution which is now sufficiently high to resolve the shape of the p-mode line profiles of solar-like stars, and in particular to measure their asymmetry. However, the physical origin of these asymmetries is still not fully understood, even for the Sun. In particular, there is no clear consensus to explain the asymmetry reversal between the velocity and intensity observables.

In this context, I will present an approach designed to better understand the physical origin of solar-like p-mode asymmetries, both in velocity and intensity. To that end, we model the spectral power density by convolving 1) the Green's function associated to the oscillating mode, which we computed numerically using a 1D evolutionary stellar model, and 2) a source term, obtained by coupling an analytical turbulence model with CO5BOLD 3D simulations of the stellar atmosphere. I will show that we successfully reproduce the observed asymmetries in the case of the Sun, both in velocity and intensity. These results allow us to better understand the physical mechanisms pertaining to solar-like p-modes, and go a long way towards explaining the asymmetry reversal puzzle.

Unveiling hidden properties of stellar rotation in open clusters with Gaia

Diego Godoy-Rivera (1); Marc H. Pinsonneault (2); Luisa M. Rebull (3)

(1) The Ohio State University; (2) The Ohio State University; (3) Infrared Science Archive (IRSA) IPAC

We use Gaia DR2 astrometry to re-assess the membership of a number of open clusters previously used in stellar rotation studies. After carefully accounting for membership, the rotational sequences of clusters observed from the ground are as clean as those of clusters with spaced-based observations (Kepler and K2). At young ages we find that virtually all M-dwarfs arrive on the main-sequence as rapid rotators (period $\lesssim$ 1 d), while at old ages (> 500 Myr) the convergence of rotation rates in hot stars (M > 0.5 $M_{\odot}$) is stronger than previously observed. The revised rotational patterns strengthen the evidence of core-envelope decoupling in K-dwarfs. Finally, Gaia data and spectroscopy have significant impacts on the relative ages and metallicities of some clusters. NGC 2516 is older than previously assumed. Praesepe and NGC6811 are more similar in age, shedding light on previous claims about puzzling stalling of rotation rates in K-dwarfs.

Center-to-limb variation of intensity perturbations caused by solar acoustic oscillations

Nadiia Kostogryz (1); Damien Fournier (2); Laurent Gizon (3)

(1) Max Planck Institut for Solar System Research; (2) Max Planck Institut for Solar System Research; (3) Max Planck Institut for Solar System Research/Institut für Astrophysik, Georg-August-Universität Göttingen

In helioseismology it is important to understand, at each position on the solar disk, the connection between the p-mode displacement vector and the seismic observable, e.g. continuum intensity. Acoustic modes perturb atmospheric thermodynamical quantities and, in turn, perturb opacity and emergent intensity. We derive analytic expressions for the emergent intensity in a solar atmosphere perturbed by acoustic oscillations, using first-order perturbation theory. Then we compute the emergent intensity by solving the radiative transfer equation in the atmosphere. The adiabatic p-mode eigenfunctions are computed using the ADIPLS eigenvalue solver in a standard spherically-symmetric solar model. Finally, we study the signature of low-degree and high-degree p modes in intensity fluctuations at different positions on the solar disk.

Spin-orbit angles and mass-radius-temperature measurements of M dwarfs in the era of TESS

Vedad Kunovac Hodžić (1); Amaury H.M.J. Triaud (2); David V. Martin (3); Pierre F. L. Maxted (4); and the EBLM team (5)

(1) University of Birmingham; (2) University of Birmingham; (3) The Ohio State University; (4) Keele University; (5) various

Since 2009, the EBLM (Eclipsing Binary Low Mass) project has been studying fully convective M dwarfs ($M < 0.3M_\odot$) eclipsing Sun-like stars, providing dozens of empirical measurements of their mass, radius, and temperature to calibrate theoretical models. While our presently reported sample does not show evidence for systematic radius inflation, we are continuing to add further measurements from our sample of > 200 known targets. As the search for Earth-sized exoplanets in habitable zones intensifies — in part due to their potential atmospheric characterisation with the upcoming JWST — mid to late M dwarfs are becoming increasingly important targets for these surveys, and thus need to be better understood to inform our knowledge on their orbiting planets.

In this work we build on the current EBLM sample by presenting ~ 20 new EBLMs with orbital periods up to ~ 15 days, and will describe the overall results of the project so far. In particular we will describe our new measurements of M dwarf masses, radii, and temperatures using data from the TESS satellite and high-precision radial velocity measurements from CORALIE and HARPS. With these new targets, we significantly increase the sample size of M dwarfs with empirically measured fundamental parameters. In addition we present accurate and precise rotation rates and spin-orbit angle measurements from Rossiter-McLaughlin sequences collected on this sample, which constitutes the largest sample of stellar obliquity measurements collected for such systems to date. Altogether, these new results allow us to better constrain stellar models for low-mass objects, and provide constraints on the tidal evolution of binary systems and circumbinary planets.

Untangling the Galaxy

Marina Kounkel, Keving Covey

Western Washington University

In the recent years, Gaia DR2 provided an incredible precision in measurements of distance and kinematics of the stars in the solar neighborhood, allowing for robust identification of clusters, associations, and comoving groups, most of which have been previously unknown. Many of these groups appear to be filamentary or string-like, oriented in parallel to the Galactic plane, and some span hundreds of parsec in length. Most of these strings lack a central cluster, indicating that their filamentary structure is primordial, rather than a result of a tidal stripping or dynamical processing. These observations shed a new light on the galactic structure, and a large-scale cloud collapse. Furthermore, isochrone fitting to these stellar groupings make possible to estimate stellar ages for an unprecedentedly large number of stars. The ages allow for a direct measurement of evolution of number of properties, from stellar to galactic.

The impact of stellar activity on orbiting planets

Adriana Valio

CRAAM, Mackenzie Presbyterian University, São Paulo, Brazil

Stellar activity manifests itself in the form of surface spots and faculae and also by flares and mass ejections from its atmosphere. When an orbiting planet transits in front of the star and occults one of these features, small signatures are imprinted in the transit light curve. These can be modeled to yield the physical characteristics of spots and faculae, such as size, temperature, location, magnetic field, and lifetime. Monitoring these signatures on multiple transits yields the stellar rotation and differential rotation, and even magnetic cycles for long enough time series. Flares have also been detected from active stars, the impact of the flaring UV flux on possible living organisms in close orbit planets is also discussed. Mass ejections also affect the planetary atmosphere being responsible for atmospheric erosion.

High Energy Phenomena around the Sun-like & Cool Stars

S. P. Moschou (1); J. J. Drake (2); O. Cohen (3); C. Garraffo (4); J.D. Alvarado-Gomez (5); F. Fraschetti (6)

(1) Harvard-Smithsonian Center for Astrophysics; (2) Harvard-Smithsonian Center for Astrophysics; (3) UMass Lowell; (4) Harvard University; (5) Leibniz Institute for Astrophysics Potsdam; (6) University of Arizona

A crucial aspect of habitability is the space environment of the planet, which can be extreme and violent for close-in planets or planets orbiting active M-dwarfs.CMEs, flares and energetic particles are the most dramatic stellar activity events. How the stored magnetic energy gets distributed between these different energetic coronal phenomena remains a vital field of research. In the Sun, more energetic solar X-ray flares are associated with faster and more massive CMEs. While highly energetic flares are continuously observed in active stars, such as M-dwarfs, stellar CMEs are elusive phenomena. In this presentation we discuss our recently published results on the stellar CME - flare relation by examining the most probable historic CME candidates, all of which were observed on magnetically active stars. When we infer the masses and kinetic energies of stellar events we find indications that in the stellar regime there is an approximately equal energy partition between flare X-ray and CME kinetic energies, contrary to the solar case where X-ray flares have 100 times less energy than their associated CMEs. Stellar CMEs with lower kinetic energies present an optimistic scenario for the impact of CMEs on close-in exoplanets. A possible mechanism responsible

for constraining the CME speeds more than their masses is the effect of strong large-scale overlying magnetic fields. A number of numerical simulations and synthetic observations have been produced to test the CME and flaring characteristics in the presence of large scale confining magnetic fields.

Lithium-rotation connection in the newly discovered young stellar stream Psc-Eri (Meingast 1)

Javier Arancibia-Silva (1); Jerome Bouvier (2); Amelia Bayo (3); Phillip A.B. Galli (4); Wolfgang Brandner (5); Hervé Bouy (6); David Barrado (7)

(1) Instituto de Física y Astronomía, Universidad de Valparaíso & Núcleo Milenio Formación Planetaria - NPF, Universidad de Valparaíso; (2) IPAG, Univ. Grenoble Alpes; (3) Instituto de Física y Astronomía, Universidad de Valparaíso & Núcleo Milenio Formación Planetaria - NPF, Universidad de Valparaíso; (4) Laboratoire d'Astrophysique de Bordeaux, Univ. Bordeaux; (5) Max Planck Institute for Astronomy; (6) Laboratoire d'Astrophysique de Bordeaux, Univ. Bordeaux; (7) Depto. Astrofísica, Centro de Astrobiología (INTA-CSIC), ESAC Campus

Context. As a fragile element, lithium is a sensitive probe of physical processes occurring in stellar interiors. Aims. We aim to investigate the relationship between lithium abundance and rotation rate in low-mass members of the newly discovered 125 Myr-old Psc-Eri stellar stream. Methods. We obtained high-resolution optical spectra and measured the equivalent width of the 607.8 nm LiI line for 40 members of the Psc-Eri stream, whose rotational periods have been derived by Curtis et al. 2019 (arXiv:1905.10588). Results. We show that a tight correlation exists between the lithium content and rotation rate among the late-G to early-K-type stars of the Psc-Eri stream. Fast rotators are systematically Li rich, while slow rotators are Li depleted. This trend mimics that previously reported for the similar age Pleiades cluster. Conclusions. The lithium-rotation connection thus seems to be universal over a restricted effective temperature range for low-mass stars at or close to the zero-age main sequence, and does not depend on environmental conditions.

Going from Near to Far to the Extreme: Using Metastable Neutral Helium to Understand Cool Stars and their Exoplanets

Teruyuki Hirano (1); Kevin France (2); Xudong Sun (3)

(1) Tokyo Institute of Technology; (2) University of Colorado; (3) University of Hawaii

The distribution of exoplanets discovered by Kepler suggests the X-ray- and UV-powered loss of of H-rich primordial atmospheres from small planets, and although atmospheric escape has been detected for a few planets, such observations have been done from space, are limited to planets around the nearest stars, and are difficult to fully interpret without information on stellar emission at extreme ultraviolet (EUV) and far ultraviolet (FUV, specifically Lyman-α) energies. EUV and FUV radiation cannot now be measured for most stars, and instead must be estimated by some proxy. The recent proliferation of ground-based high-resolution infrared spectrographs on ground-based telescopes has enabled observations of transiting planets in the 10830Å near-infrared line of metastable He I and opened a new window on the escape of planetary atmospheres, and multiple detections and useful upper limits have been reported. Stellar metastable He I lines are themselves potential proxies for EUV emission in planet-hosting stars, since metastable He I is produced by recombination of He II which, in turn, is the product of EUV photoionization. We review (a) recent observations of the He I line in transiting exoplanets, particularly young systems; (b) lessons from the Sun regarding the origin of the infrared He I line, its spatial distribution and temporal variation, and both

potential source of systematic errors in transit measurements as well as a proxy for EUV emission; and (c) a proposed synergistic combination of space- and ground-based observations to improve our understanding of the He I lines and EUV emission of other solar-type stars and M dwarfs, with the potential to significantly advance our understanding of exoplanet atmosphere evolution.

Stellar Flares and Habitable M-dwarf Worlds with TESS

Günther, M.

MIT

Finding and characterizing small exoplanets transiting cool stars naturally poses the question of their habitability. A major contributing factor to this might be stellar flares, originating from powerful magnetic reconnection events on the star. While too powerful flaring can erode or sterilize exoplanets' atmospheres and diminish their habitability, a minimum flare frequency and energy might be required for the genesis of life around M dwarfs in first place. In this talk, I will first highlight our TESS study of stellar flares, linking our findings to prebiotic chemistry and ozone sterilization; we already identified thousands of flaring stars, including many young, rapidly rotating M dwarfs, some showing superflares with over 30x brightness increase in white light. Further, I will discuss our search for planets and low-mass companions transiting these chaotic stars, always with an eye on the Goldilocks range of flaring activity. With upcoming TESS sectors, stellar flare studies and new exoplanet discoveries will ultimately aid in defining criteria for exoplanet habitability.

Low-mass pre-main sequence stars and their disks: a story of the dawn of planets

Carlo F. Manara

European Southern Observatory (ESO)

The pre-main sequence phase of the evolution of young stars and their circumstellar disks is key to understand how planets form. In this talk I will present the results of spectroscopic surveys of hundreds of pre-main sequence low-mass stars in nearby star-forming regions, with the goal to describe our current understanding of the pre-main sequence evolution. I will then show how the combination of the stellar and accretion properties of these stars with the circumstellar disk properties are key to constrain how planets form.

Mapping the Progression of Star Formation in the Sco-Cen Association

Ronan M. P. Kerr; Aaron C. Rizzuto; Adam L. Kraus

University of Texas at Austin

The Sco-Cen OB association is the nearest site of recent large-scale star formation to the sun (100-150pc) and contains roughly 10000 members. Due to its diversity, large size, complex star formation history, and relative accessibility due to distance, Sco-Cen provides an ideal environment in which to study the output of star formation prior to dissipation into the galactic disk. With the most recent data from Gaia DR2, it is now possible to study the star-formation history and substructure of Sco-Cen in detail. I have used Gaia photometry and parallaxes to identify young stars using an isochrone-generated model stellar population. Analyzing all high-quality Gaia stars with parallax > 3 mas, I have identified about 18000 stars on the pre-main sequence with photometric ages of less than 30 Myr, including members of previously unidentified associations. Gaia proper motion measurements reveal that nearly 5700 of these pre-main sequence stars are members of Sco-Cen. My results reveal the internal structure of the association, and describe the formation, motion, and subsequent dispersal of these young stars throughout the region's history.

Radiative MHD Simulations of Starspots and their spectral synthesis

Mayukh Panja; Robert Cameron; Sami Solanki

Max Planck Institute for Solar System Research

We have performed the first-ever, realistic 3D simulations of the photospheric structure of complete starspots, including their penumbrae, for a range of cool main-sequence stars, namely the spectral types M0V, K0V, and G2V. We used the MHD code MURaM which includes radiative energy transfer and the effects of partial ionization. We explore several fundamental properties like umbral intensity contrast, temperature, and magnetic field strength as functions of spectral type. Our simulations show that there is an increase in spot contrast with the increase in stellar surface temperature, which is consistent with observations. The umbral field strength is determined by the depth at which the optical surface forms and the surface pressures of the host stars. We will present our results and discuss the physics behind them. Subsequently, we synthesized several spectral lines from our simulated starspot atmospheres in the visible and infrared wavelengths and studied the center-to-limb variations of the emergent spectra.

Slingshot prominences as a mechanism for mass and angular momentum loss in young M-dwarfs

Rose F.P. Waugh; Moira M. Jardine

University of St Andrews

Slingshot prominences are cool condensations of plasma that are enforced in co-rotation with rapidly rotating stars. They are typically 10-100 times the mass of solar prominences and form around the co-rotation radius of a star (rather than a few km above the solar surface). They have been most well observed on the young-Sun AB Doradus, although they have been observed in a range of systems, including on M-dwarfs. Their prevalence across the stellar spectrum suggests that these features could be common within low mass stars. The prominence material is known to be supported in co-rotation by the stellar magnetic field, thus the locations of these features allow for inferring of the field structure at these locations. Their ejection from the star could also be a mass or angular momentum loss mechanism for the star in its youth, when the prominences are large and held multiple stellar radii above the stellar surface. We investigate the formation of these prominences in a sample of M-dwarfs. Using Zeeman Doppler Imaging maps of our stellar sample, the magnetic field structure within the corona can be constructed, assuming a potential field. The prominence formation sites for these stars on these particular years was then modelled by searching for the stable equilibrium locations within the constructed field topologies. All maps used result in predicted prominence formation sites, though in many cases we predict that these prominences would not have been visible from Earth due to the geometry of the system. Despite our prediction that most of these stars would not have hosted any prominences visible to us, we show that these features

should not be ignored. We compare the mass and angular momentum loss rates of the prominences to the stellar isothermal wind, showing that in some cases the prominence mass lass rates can be greater than the wind itself.

Understanding peculiar cool members to trace globular cluster hectic infancy

Corinne Charbonnel

(1) Department of Astronomy, University of Geneva; (2) CNRS IRAP Université de Toulouse

Globular clusters (GC) are magnificent astronomical objects that provide insight to a broad variety of astronomical and cosmological questions. These compact systems hosting between several hundreds of thousands and a million of cool stars provide fundamental benchmarks for stellar evolution theory. Being among the oldest structures in the Universe, they are unique relics, witnesses, and clocks of the assembly, dynamics, and evolution of galaxies and of their substructures, from the early to the present-day Universe. They play a key role in hierarchical cosmology, and potentially also in the reionization of the Universe. However, their formation, evolution, and survival in a galactic and cosmological context are far from being understood.

The discovery of multiple stellar populations in globular clusters both in the Milky Way and in Local Group galaxies recently brought a renewal on these questions. In this talk, I will review the chemical and photometric characteristics of these very peculiar cool stars, and discuss the various scenarios that have been developed to explain their origin. I will focus on the (many) current theoretical issues and open questions.

Brown dwarfs in open clusters silver anniversary

Eduardo L. Martín; Rafael Rebolo; Maria Rosa Zapatero Osorio

Instituto de Astrofísica de Canarias and CSIC-INTA Centro de Astrobiología (Spain)

25 years ago we presented the discovery of Teide Pleiades 1, the first bona-fide brown dwarf in the Pleiades cluster, at the 9th Cool Stars meeting in Florence. 12 Cool Stars later, we aim to present a historical perspective of the development of this field of research, its current status and a glance into what comes next with upcoming facilities, with particular emphasis on wide angle surveys such as those planned with the Euclid space mission.

New empirical relations on fundamental parameters from HK-band spectral indices of K–M giants

D. K. Ojha (1); S. Mondal (2); R. K. Das (3)

(1) Tata Institute of Fundamental Research, Mumbai, India; (2) S. N. Bose National Center for Basic Science, Kolkata, India; (3) S. N. Bose National Center for Basic Science, Kolkata, India

Precise estimation of fundamental parameters (effective temperature, surface gravity, metallicty) from spectral signatures of K–M giants is very important to characterize the stellar population in different environments. However, it remains a challenge because of their molecular near-photospheric environment. We explore the behavior of H and K spectral features of those giants with fundamental

parameters using our observations and archival spectral library and compare them with theoretical spectral grids. The behavior of spectral features predicted from theoretical model spectra appears to behave similarly with the observations in the range 5000 to 3000 K. Below 3000 K, the behavior is inconclusive from the observed data because of the lack of the sample. In addition, we derive new empirical correlations, which can predict effective temperature, surface gravity and metallicity with a typical accuracy 100 K, 0.3 dex and 0.2 dex, respectively.

Understanding and Modelling the Magnetic Cycles of Slowly Rotating Stars: Consequence of Anti-solar Differential Rotation

Vindya Vashishth, Aparna Tomar, Suyog Garg

Indian Institute of Technology (BHU), Varanasi

The Sun and many other sun-like low-main sequence stars have active magnetic fields and cycles. Cycles of many sun-like stars show some similar properties as that of solar cycle. Therefore, it is believed that the dynamo mechanism(s) operating in stellar convection zones are responsible for the generation of stellar cycles. Simulations of magnetohydrodynamics convection in slowly rotating stars predict anti-solar differential rotation (DR) in which the equator rotates slower than poles. This anti-solar DR in the usual alpha Omega dynamo model does not produce polarity reversal. Thus, the features of large-scale magnetic fields in slowly rotating stars are expected to be different than stars having solar-like DR. In our study, we perform mean-field kinematic dynamo modelling of different stars at different rotation periods. We show that with particular alpha profiles, the dynamo model produces magnetic cycles with polarity reversals even with the anti-solar DR provided, the DR is quenched when the toroidal field grows considerably high and there is a sufficiently strong alpha for the generation of toroidal field. Due to the anti-solar DR, the model produces an abrupt increase of magnetic field exactly when the DR profile is changed from solar-like to anti-solar. This enhancement of magnetic field is in agreement with the stellar observational data as well as some global convection simulations. In the solar-like DR branch, with the decreasing rotation period, we find the magnetic field strength increases while the cycle period shortens. Both of these trends are in general agreement with observations.

Planetary engulfment as a possible explanation for unusually rapidly-rotating old main-sequence stars

A.Oetjens (1); Maria Bergemann (2); Ludmila Carone (3)

(1) Ruprecht-Karls Universität, Heidelberg, Germany and Max-Planck-Institute for Astronomy, Heidelberg, Germany; (2) Max-Planck-Institute for Astronomy, Heidelberg, Germany; (3) Max-Planck-Institute for Astronomy, Heidelberg, Germany

Gyrochronology - the analysis of stellar rotation - is a standard astronomical method to determine the ages of stars. Since the fundamental (Skumanich 1972) relationship that predicts that main-sequence stars spin down as t-0.5, this canonical method has been widely used to provide a diagnostic of stellar ages (Angus et al. 2019). However, recent advances in age tagging of stars by asteroseismology have revealed severe discrepancies with ages derived by gyrochronology (e.g. Sahlholdt et al. 2019). In this work, we explore whether the tension could be explained by the tidal interaction of a massive planetary companion with its host star. We develop a new model that describes the evolution of angular momentum of main-sequence stars in the presence of a Jupiter-mass planet. Our model relies on analytical recipes for angular momentum evolution (Bouvier 1997),

tidal friction (Privitera et al. 2016), and stellar spin-up (Carone 2012). We apply this model to an ensemble of synthetic star-planet configurations. We find that, in most cases, the dynamical evolution of the star-planet system leads to a gradual spin-up of the main-sequence star from a few km/s up to 40 km/s. But the time it takes for planet to be engulfed by the star depends on the initial orbit, mass and metallicity of the system. We compare our results with a large observed sample of stars with accurate measurements of [Fe/H], masses, and rotation periods (McQuillan et al. 2014, Berger et al. 2020). The data suggest that a significant fraction of metal-poor old main-sequence stars exhibit very high rotation rates, in stark contrast with canonical gyrochronology models. In our scenario, this can be naturally explained by the interaction of a star with its planet. We are able to confine the mass-orbit parameter space of the planet, before the engulfment happened. Our model provides a viable alternative to more complex and poorly-understood scenarios, such as the inefficiency of magnetic breaking. In summary, our results suggest that the observed distributions of rotation periods and metallicities of stars in the Galaxy can be explained by the dynamical interaction in a star-planet system, and it may also explain the discrepancies between gyrochronology and asteroseismology regarding the ages of stars.

The Wilson-Bappu effect revisited

Faiber Rosas; Klaus-Peter Schröder; Dennis Jack

Departamento de Astronomía, Universidad de Guanajuato

The Wilson-Bappu effect (Wilson & Bappu, 1957) is a well-known empirical relationship for cool stars and giants between the emission line width of Ca II K (W_0) and the absolute visual magnitude (M_V). To date, however, the underlying physical relationship of W_0 with stellar parameters, in particular gravity and effective temperature, has not been fully established, nor its physical nature. This motivated us to find the physical relationship of the WBE by current means, using a sample of 25 well-known late-type stars and their Gaia DR2 parallax to obtain exact luminosities. We measure W_0 and determine consistent stellar temperatures from TIGRE-HEROS spectra (R $\sim$ 20000) of high signal to noise synthesized with the iSpec tool. Gravities were derived from the latter and a mass estimate. As expected, we found a strong dependence of W_0 on surface gravity, plus a weaker effective temperature term. Our result supports the theoretical explanation of Ayres et al., 1975, of the WBE as a simple line saturation effect, caused by the mass density of the chromosphere column (proportional to g$^{-0.5}$ in hydrostatic equilibrium). Consequently, the temperature comes from the Ca II: Ca I ionization ratio, which allows for larger Ca II column densities at higher temperatures.

A Large-Scale Homogeneous Analysis of Substellar Model Atmospheres

Zhoujian Zhang (1); Michael C. Liu (2); Mark S. Marley (3); Michael R. Line (4); William M. J. Best (5)

(1) Institute for Astronomy, University of Hawaii; (2) Institute for Astronomy, University of Hawaii; (3) NASA Ames Research Center; (4) School of Earth and Space Exploration, Arizona State University; (5) Department of Astronomy, University of Texas at Austin

Spectroscopy is a fundamental tool for investigating ultracool atmospheres and their impact on the evolution of brown dwarfs and imaged exoplanets. Such work relies on construction of accurate model atmospheres, a challenging task given the complex physical and chemical processes. To validate these models, we are focusing on a well-known, but not fully appreciated, resource: the

numerous high-quality spectra of substellar and planetary-mass objects already published. While most previous work has studied only individual or small groups of objects, we are analyzing a large sample of spectra using the latest models (the Sonora grid) and modern Bayesian inference (the Starfish methodology). Our work is the first homogenous analysis of substellar model atmospheres in over a decade, with the goal of enabling robust characterization of brown dwarfs and exoplanets from their spectra.

We present here a large-scale forward-modeling analysis of 55 late-T dwarfs ($\sim$600-1200 K, $\sim$10-70 Jupiter masses), constituting a >4x larger sample than any previous work, as well as being the first study to use models with both solar and non-solar metallicities. We derive the objects' properties (temperature, gravity/age, and metallicity) and compare them to nearby stars to examine whether the substellar and stellar populations in the solar neighborhood have similar formation histories. To identify the shortcomings in the predictions, we stack the spectral-fitting residuals of all our objects to identify model imperfections as a function of wavelength, temperature, gravity, and metallicity. As a novel method to verify the assumptions made within the models, we also compare our forward-modeling results to inverse-modeling (a.k.a. retrieval) analysis of the same sample. Finally, we discuss extending our work to wider temperature and wavelength (e.g., JWST) ranges, as well as finding more brown dwarf benchmarks to validate the models.

Revisiting the census of pre-main sequence stars in the Lupus star-forming region

Phillip Galli (1); Hervé Bouy (2); Javier Olivares (3); Nuria Miret-Roig: Luis Manuel Sarro (4); David Barrado (5); Angel Berihuete (6)

(1) LAB/Université de Bordeaux; (2) LAB/Université de Bordeaux; (3) LAB/Université de Bordeaux; (4) LAB/Université de Bordeaux; (5) Depto. de Inteligencia Artificial/UNED; (6) Centro de Astrobiologia/INTA-CSIC; (7) Dept. Statistics and Operations Research/University of Cádiz.

Lupus is a nearby low-mass star-forming complex that contains four molecular clouds (Lupus 1 to 4) with recent and ongoing star formation. It contains one of the richest associations of T Tauri stars from the Solar neighbourhood that have been spectroscopically identified and characterised over the last decades. The proper motions and parallaxes delivered recently by the Gaia space mission reveal that many of the classical members are background sources most probably unrelated to Lupus or likely members of the adjacent Scorpius-Centaurus association. We have revised the census of Lupus stars based on a probabilistic method to infer membership probabilities using Gaia-DR2 astrometry and photometry. We present in this study an updated sample of Lupus stars and discuss the properties (distance, kinematics and age) of the various subgroups in this region.

A very long and hot X-ray superflare on an RS CVn type eclipsing binary SZ Psc

Subhajeet Karmakar (1); Sachindra Naik (2); Jeewan C. Pandey (3); Igor S. Savanov. (4)

(1) Physical Research Laboratory, Ahmedabad- 380009, India; (2) Physical Research Laboratory, Ahmedabad- 380009, India; (3) Aryabhatta Research Institute of observational Sciences, Nainital 263002, India; (4) Institute of Astronomy, Russian Academy of Sciences, ul. Pyatniskaya 48, Moscow 119017, Russia

We present an analysis of a very large flare from the 3.966-day period RS CVn type eclipsing binary system SZ Psc which triggered the Swift Burst Alert Telescope (BAT) hard X-ray detector at 09:08:42

UT on 15 January 2015. We found that the flare is out of eclipse. It lasts for more than 1.3 days, and it is one of the longest duration X-ray flares ever observed. The exponential rise and decay time of the flares were derived to be 2 and 5 hr, respectively. The peak X-ray luminosity in the 0.3-10 keV energy band reached a value of 4.8×10^{33} erg s^{-1}, which is 89 times more than that of the observed minimum value. For the first time, detailed high-resolution X-ray spectroscopy is performed on this object, and we found the evidence of three temperature corona. Two cooler temperatures of 4 and 13 MK are identified as the quiescent corona, whereas the hottest one is found to vary during the flare and is identified as flare temperature. The peak flare temperature is found to be one of the highest observed spectroscopically with a derived value of 258 MK, which is $\sim$10 times more than the observed minimum value. The peak stellar abundances were derived to be 0.7 times more than solar abundances, which is also 10 times more than that of the minimum abundance observed on SZ Psc. The Emission Measure followed the flare light curve and peaked at a value of 2.53×10^{54} cm^{-3}, which is $\sim$17 times more than the quiescent value. The length of the flaring plasma was derived to be 7.3×10^{11} cm, whereas the loop apex pressure and the peak density were derived to be 9.1×10^{4} dyne cm^{2} and 5.8×10^{11} cm^{-3}, respectively. The total magnetic field estimated to produce the flare is 1.5 kG. The analysis suggests that the large magnetic field at the coronal height is due to the presence of extended convection zone of the sub-giant and the high orbital velocity.

Small-scale dynamo in cool main-sequence stars

Tanayveer S. Bhatia; Robert H. Cameron; Hardi Peter; Damien Przybylski

Max Planck Institute for Solar System Research

Context: The presence of (unresolved) small-scale mixed polarity regions in the quiet Sun photosphere plays an important role in determining the basal small-scale magnetic flux. Observationally, the strength of the vertical unsigned component of this field is estimated to be in the range of 50-100 G on the Sun. This field is important, e.g., for determining the energy balance in the chromosphere, and it may also subtly affect the radiative properties of the solar photosphere. These fields are believed to be the result of a small-scale dynamo (SSD) operating in the near-surface magneto-convection.

Aim: While significant progress has been made in investigating the role of the SSD in the Sun, it is unclear what properties and effects SSDs have on other stars. We aim to characterize the effect of the SSD on additional cool spectral types.

Methods: Box simulations of the upper convection zone and the photosphere are carried out using the radiative MHD code MURaM. To obtain SSD simulations, we use initial hydrodynamic simulations and seed a magnetic field of negligible strength and zero net flux, which we then run till the magnetic field reaches saturation. We consider four stellar types, F, G, K and M, where we take the Sun as a reference G star.

Results: All investigated spectral types exhibit an SSD. We find the photospheric ($\tau = 1$) absolute vertical field ($< |B_z| >$) to increase with increasing effective temperature. The spatial power spectra of the bolometric intensity shows deviations from corresponding hydrodynamic (without magnetic field) runs, implying larger power at smaller spatial scales for SSD case.

Conclusions: The presence of a SSD results in a significant amount of "quiet"-star magnetic flux with associated changes in the spatial distribution of the bolometric intensity. These results will have important consequences for the inclusion of quiet-star magnetic fields in stellar atmosphere models.

Contribution of active-region inflows to variations in the solar meridional flow

Paul-Louis Poulier (1); Laurent Gizon (2); Zhi-Chao Liang (3); Thomas L. Duvall, Jr. (4); Damien Fournier (5)

(1) Max Planck Institute for Solar System Research; (2) Max Planck Institute for Solar System Research & Institute for Astrophysics, Georg-August-Universität Göttingen; (3) Max Planck Institute for Solar System Research; (4) Max Planck Institute for Solar System Research; (5) Max Planck Institute for Solar System Research

Meridional circulation can be inferred throughout the solar convection zone with helioseismology. Here we study the contribution of active-region inflows to the north-south helioseismic travel times, in order to better understand the time-dependent component of the solar meridional circulation. We use maps of horizontal flows at the surface obtained by tracking granules and small magnetic features in SDO/HMI images. From these maps we extract the flows surrounding the active regions and compute the corresponding helioseismic travel-times perturbations. Finally we discuss whether or not active-region inflows can explain all solar-cycle variations of the meridional flow.

Common dynamo scaling in young and evolved stars

Jyri J. Lehtinen (1); Federico Spada (2); Maarit J. Käpylä (3); Nigul Olspert (4); Petri J. Käpylä (5)

(1) Max Planck Institute for Solar System Research & Aalto University; (2) Max Planck Institute for Solar System Research; (3) Aalto University & Max Planck Institute for Solar System Research; (4) Max Planck Institute for Solar System Research; (5) Institut für Astrophysik, Georg-August-Universität Göttingen & Aalto University

We present a study investigating the rotation-activity relation of both young and evolved stars, based on rotation periods and chromospheric Ca II H&K emission levels derived from the Mount Wilson Observatory HK Project observations. This survey contains stars with a wide range of activity levels and evolutionary stages, spanning from young main sequence stars to red giants. We show that the observed activity levels of the main sequence and evolved stars can only be explained in a uniform way when the activity levels are correlated against the Rossby numbers of the stars, defined as the ratio of the rotation period to the convective turnover time ($\mathrm{Ro} = P_{\mathrm{rot}}/\tau_{\mathrm{c}}$). We obtained the Rossby numbers uniformly for the stars across our sample by deriving their convective turnover times from model stellar evolutionary tracks from the Yale-Potsdam Stellar Isochrones. Alternate proposed activity scaling relations, that do not parametrise convection, are not able to explain the activity levels of both the main sequence and evolved stars simultaneously. Our results show that there is a common dynamo mechanism explaining the magnetic activity of all late-type stars, independent of their evolutionary stage. Moreover, turbulent convection is necessarily a fundamental building block of this dynamo mechanism.

Spatially resolving the inner regions of FU Ori: Revealing the temperature structure actively accreting disks

Stefan Kraus (1); Claire L. Davies (2); Alexander Kreplin (3); Tim J. Harries (4); John D. Monnier (5); Jean-Baptiste le Bouquin (6); Narsireddy Anugu (7); Theo ten Brummelaar (8); Judit Sturmann (9); Lazlo Sturmann (10)

(1) University of Exeter; (2) University of Exeter; (3) University of Exeter; (4) University of Exeter; (5) University of Michigan; (6) Institut de Planétologie et d'Astrophysique de Grenoble; (7) Steward Observatory universty of Arizona; (8) The CHARA Array of Georgia State University; (9) The CHARA Array of Georgia State University; (10) The CHARA Array of Georgia State University

Optical Interferometry allows us to observe the innermost regions of young stellar objects where accretion processes dominate these complex environments. Investigating accretion mechanisms is key to understanding stellar and disk evolution in the early stages, particularly for cool stars. FUor stars are a key part of this process, undergoing rapid outbursting event during which accretion rates increase many orders of magnitude over short timescales. Once thought to be rare occurrences, it is now thought FUor outbursts are common throughout the lifecycle of many T Tauri stars. Using Multi-wavelength interferometry we are able to provide new constraints of the stellar and disk properties, in addition to revealing the temperature structure of the archetypal FUor star across the innermost regions of this heavily accreting outbursting object.

Revisiting Proxima with ESPRESSO

Suárez Mascareño Alejandro; Faria, Joao P.; Figueira, Pedro; Lovis, Christophe; Damasso, Mario; González Hernández, J. I. and the ESPRESSO consortium.

Instituto de Astrofísica de Canarias/Universidad de La laguna, Instituto de Astrofísica e Ciências do Espaço, ESO, Observatoire astronomique de l'Universitè de Genève, iNAF, Instituto de Astrofísica de Canarias & other.

The discovery of Proxima b marked one of the most important milestones in the recent years of exoplanetary science. Yet, the limited precision of the available radial velocity data and the difficulty in modeling the stellar activity prevented an undisputed detection of the Earth-mass planet. Using the unprecedented precision of the new ESPRESSO spectrograph we independently confirm the presence of Proxima b.The ESPRESSO data on its own shows Proxima b at a period of 11.2 days, with a minimum mass of 1.26 Me. We find that for the case of Proxima, the FWHM of the CCF can be used as a proxy for the brightness changes and that its gradient with time can be used to successfully detrend the radial velocity data from part of the influence of stellar activity. We see a chromatic effect on the activity component across the spectral range of the ESPRESSO RVs, with its amplitude decreasing towards redder wavelenghts. This two findings combined suggest the active regions responsible for the RV changes are most likely spots, and that those spots follow a fairly simple geometrical distribution over the stellar surface.

The dust sublimation rim of the disc of RY Tau: insights into the origin of its aperiodic photometric variability using near-infrared interferometry

Claire L. Davies (1); Stefan Kraus (2); Alexander Kreplin (3); Tim J. Harries (4); John D. Monnier (5); Brian Kloppenborg (6); Alicia Aarnio (7); Narsireddy Anugu (8); Fabien Baron (9); Jean-Baptiste Le Bouquin (10); Jacob Ennis (11); Rebeca Garcia Lopez (12); Tyler Gardner (13); Aaron Labdon (14); Cyprien Lanthermann (15); Rafael Millan-Gabet (16); Robert Parks (17); Ettore Pedretti (18); Karine Perraut (19); Benjamin Setterholm (20); Judit Sturmann (21); Laszlo Sturmann (22); Theo A. ten Brummelaar (23); Yamina Touhami (24)

(1) Astrophysics Group, School of Physics, University of Exeter, Stocker Road, Exeter, EX4 4QL, UK; (2) Astrophysics Group, School of Physics, University of Exeter, Stocker Road, Exeter, EX4

4QL, UK; (3) Astrophysics Group, School of Physics, University of Exeter, Stocker Road, Exeter, EX4 4QL, UK; (4) Astrophysics Group, School of Physics, University of Exeter, Stocker Road, Exeter, EX4 4QL, UK; (5) Department of Astronomy, University of Michigan, Ann Arbor, MI 48109, USA; (6) Department of Physics and Astronomy, Georgia State University, Atlanta, GA, USA; (7) University of Colorado Boulder, 3665 Discovery Drive, Boulder, CO 80303 USA; (8) Steward Observatory, Department of Astronomy, University of Arizona, Tucson, USA; (9) Department of Physics and Astronomy, Georgia State University, Atlanta, GA, USA; (10) Institut de Planetologie et d'Astrophysique de Grenoble, Grenoble 38058, France; (11) Department of Astronomy, University of Michigan, Ann Arbor, MI 48109, USA; (12) School of Physics, University College Dublin, Belfield, Dublin 4, Ireland; (13) Department of Astronomy, University of Michigan, Ann Arbor, MI 48109, USA; (14) Astrophysics Group, School of Physics, University of Exeter, Stocker Road, Exeter, EX4 4QL, UK; (15) Institut de Planetologie et d'Astrophysique de Grenoble, Grenoble 38058, France; (16) Infrared Processing and Analysis Center, California Institute of Technology, Pasadena, CA, 91125, USA; (17) Department of Physics and Astronomy, Georgia State University, Atlanta, GA, USA; (18) STFC Rutherford Appleton Laboratory, Harwell Science & Innovation Campus, OX11 0QX, United Kingdom; (19) Univ. Grenoble Alpes, CNRS, IPAG, 38000 Grenoble, France; (20) Department of Astronomy, University of Michigan, Ann Arbor, MI 48109, USA; (21) The CHARA Array of Georgia State University, Mount Wilson Observatory, Mount Wilson, CA 91203, USA; (22) The CHARA Array of Georgia State University, Mount Wilson Observatory, Mount Wilson, CA 91203, USA; (23) The CHARA Array of Georgia State University, Mount Wilson Observatory, Mount Wilson, CA 91203, USA; (24) Department of Physics and Astronomy, Georgia State University, Atlanta, GA, USA

RY Tau is a young, $\sim 2\,\mathrm{M}_\odot$ pre-main-sequence star hosting a circumstellar disc and exhibiting mirco-jet emission. The disc has long been identified as pre-transitional based on its spectral energy distribution while millimetre imaging reveals an annular dip in surface brightness at ~ 18 au. In this talk, I will present results from two near-infrared interferometric studies of this object and reveal the structure of the inner disc for the first time. Firstly, I will focus on K-band interferometry obtained with the CLIMB (three telescope) beam combiner of the CHARA Array. By comparing our observations to TORUS Monte Carlo Radiative Transfer simulations, I will show that the inner disc rim is shaped by dust sublimation and extends inward to within ~ 0.2 au of the star (an order of magnitude further from the star than the magnetospheric truncation radius). The second part of my talk will focus on multi-epoch H-band interferometry with the MIRC-X (six telescope) combiner of the CHARA Array during the first two years of its operation. With MIRC-X's improved sensitivity and greater image plane sampling, we have been able to directly observe temporal evolution of the disc rim structure. I will discuss these remarkable results in the context of young stellar object photometric variability.

Shedding light on solar radial velocity variations

Annelies Mortier (1); Jessica Copeland (2); Christopher Watson (3)

(1) University of Cambridge; (2) Royal Holloway, University of London; (3) Queen's University Belfast

The radial velocity technique is currently the best method to characterise the planet mass of exoplanets. Unfortunately, for smaller or longer period planets, this technique is hindered by stellar activity which gives rise to radial velocity variations up to several times larger than these exoplanetary signals. Since July 2015, HARPS-N has been observing the Sun-as-a-star, making it possible to coherently study radial velocity variations due to stellar activity as we are certain there are no planetary signals in this dataset. In this talk, I will show one way of learning from this data. We have used solar light curves in various wavelengths, SDO intensity images, and the HARPS-N radial

velocities to investigate the relation between photometric and radial velocity variations and activity complexity on the solar surface.

Abundance analysis of individual elements for M dwarfs with high-resolution near-infrared spectroscopy

Wako Aoki (1); Takayuki Kotani (2); Masashi Omiya (3); Masayuki Kuzuhara (4)

(1) SOKENDAI, NAOJ; (2) Astrobiology Center, NAOJ, SOKENDAI; (3) Astrobiology Center, NAOJ; (4) Astrobiology Center, NAOJ

M dwarfs are the main component in the stellar mass of our Galaxy and have been recently the prominent targets of planet search projects. However, it has been problematic to determine their elemental abundances. We here demonstrate the comparison of the abundances of individual elements between each component of G/K-dwarf + M-dwarf visual binaries. Using the published data of the CARMENES planet survey, we measured the equivalent widths of atomic lines in the high-resolution near-infrared spectra for the M-dwarf components. While we confirmed that the abundances of Fe, Ca, Ti, and Cr derived for the early M dwarfs well agree with those of primary stars, the abundances we derived for mid-M dwarfs are systematically lower than those of primaries by $\sim$0.2 dex. Through the analysis, we found that many atomic lines are not sensitive to the abundance changes of the corresponding element itself and are not useful for abundance measurements. One reason for this insensitivity is that the abundances of elements with low ionization potential (e.g. Na, Ca) affect all the lines via the continuum opacity. This indicates that it is important to determine the abundances of individual elements and apply the consistent abundance ratios to the analysis of each object for the determination of the metallicity or abundance ratios.

Revolutionising our understanding of Sun-like stars through extremely precise radial velocities

H. M. Cegla (1); R. D. Haywood for the NASA-NSF EPRV Working Group (2)

(1) University of Warwick; (2) University of Exeter

Following the recommendations made in the 2018 Exoplanet Science Strategy report to the US National Academies, NASA and the US National Science Foundation have jointly commissioned an Extreme Precision Radial Velocity Working Group (EPRV WG). The WG has developed a roadmap for a strategic initiative on how to reach the RV precision necessary to confirm a true Earth analog around a Sun-like star. The fundamental limiting factor to this endeavour is our understanding of the intrinsic magnetic variability of the host stars. Here, we present an overview of the WG findings and recommendations.

Please note this submission is for a joint talk. If accepted as a plenary, neither authors will speak in the related Splinter on EPRV.

Stellar coronal X-ray emission and surface magnetic flux

Juxhin Zhuleku; Jörn Warnecke; Hardi Peter

Max Planck Institute for Solar System Research, Göttingen, Germany

The X-ray activity of the Sun and solar-like stars is governed by the magnetic field on the stellar surface. This is observationally well established with numerous studies providing power-law scalings between the magnetic flux at the solar or stellar surface and the emerging coronal X-ray emission. A clear theoretical basis for this observational finding is lacking. In our study, we aim to provide a quantitative understanding of the power-law relation between X-ray emission and magnetic field through a simple analytical analysis and numerical 3D MHD models of solar and stellar coronae. In our analytical model, we start from the Rosner-Tucker-Vaiana (RTV) scaling laws for coronal loops, which relate temperature and pressure to heat input and loop length. To this, we add how the X-ray emission depends on coronal temperature for different X-ray instruments and different scalings for coronal heating mechanisms, e.g. Alfven waves and nanoflares. Combining these, we derive a power-law scaling between X-ray emission and magnetic flux, where the power-law index depends mainly on the form of the heating mechanism and the temperature response of the instrument. In particular, for nanoflare heating, we find a good agreement between our simple model and observed power-law relations. To get more flexibility and relax the 1D assumption of the RTV laws in the analysis, we also derive power-law scalings using numerical 3D MHD models of solar and stellar coronae above active regions. Starting from a typical solar active region as a reference, we scale the magnetic flux of the active region by increasing (a) the peak magnetic field strength and (b) the area of the active region. In both cases, we find a power-law relation between X-ray emission and magnetic flux that is steeper than in most of the observational studies and our simple analytical approach. With the outcome of these analytical and numerical studies, we can better understand how different properties of stellar active regions, e.g. overall active region size, peak magnetic field strength, filling factor or the presence of large- and small-scale magnetic field patches, will scale with stellar activity and hence impact the X-ray emission. Our analytical model already gives a good quantitative understanding of how the stellar X-ray emission depends on the surface magnetic flux. With the numerical models, we can investigate the complex chain of processes that governs the X-ray emission and by this gain better quantitative insight into the stellar X-ray activity.

Stellar Rotation Rates As Seen By TESS

Danielle Rowland (1); Ruth Angus (2)

(1) American Museum of Natural History; (2) American Museum of Natural History, Flatiron Institute, Columbia University

Although TESS is a mission optimized to search for planet transits, the abundance of time-series data collected also provides an opportunity to study stellar activity. Our understanding of stellar rotational evolution was advanced by the Kepler mission and the catalogs of rotation period measurements that resulted from its 4 year light curves. Unlike Kepler, TESS has all-sky coverage, so we can explore additional stellar populations in different areas of the sky to test the evolution of rotation periods. With the first observations in the Southern Continuous Viewing Zone (CVZ) complete, the 13 overlapping sectors of data can be stitched together to provide nearly year long light curves for stars in this region. Following established periodic signal detection methods that utilize lomb-scargle periodograms and autocorrelation functions, we have measured rotation periods for 2-minute cadence stars in the Southern CVZ. We find trends in this new sample of rotation periods that reflect those seen in the Kepler sample, however, measuring stellar rotation rates longer than $\sim$12 days has proven difficult. In this talk, I will summarize our results and provide an overview of the challenges we encountered measuring stellar rotation periods with TESS.

The Galactic cosmic ray intensity at the evolving Earth and young exoplanets

Donna Rodgers-Lee, Aline Vidotto, Andrew Taylor, Paul Rimmer, Turlough Downes

(1) University of Dublin, Trinity College; (2) University of Dublin, Trinity College; (3) DESY; (4) University of Cambridge; (5) Centre for Astrophysics & Relativity, Dublin City University

Cosmic rays may provide an important source of ionisation for exoplanetary atmospheres. The properties of the solar wind, such as the magnetic field strength and velocity profile, evolve with time. This means that the intensity of Galactic and stellar cosmic rays which reach Earth, by interacting with the solar wind, will also vary as a function of the Sun's life-time. Generally, young solar-type stars are very magnetically active and are therefore thought to drive stronger stellar winds. I will present our recent results which simulate the propagation of Galactic cosmic rays through the heliosphere as a function of the Sun's life. I will focus on the intensity of Galactic cosmic rays at particular times in the Sun's past, such as when life is thought to have begun (approximately 3.8Gyr ago) and 600Myr which is relevant for the exoplanetary system, HR 2562b orbiting a $\sim$Sun-like star. I will also examine the conditions that may be present when the Sun is a $\sim$Gyr older than its current age. Finally, I will discuss the possible chemical signatures that we might expect from Galactic cosmic rays.

What do Precision Light Curves Really tell us about Starspots?

Gibor Basri; Riya Shah; Joanne Tan; Lawrence Edmond; Michelle Lee

UC Berkeley

The era of lengthy observations of precision stellar light curves began 15 years ago. The Kepler Prime mission collected the largest number of them with multi-year nearly continuous coverage. Many complex behaviors are seen, which suggests the potential to learn a lot about starspot variability (perhaps even activity cycles), starspot lifetimes, and even differential rotation on thousands of F-M main sequence stars. While we did learn a lot about stellar rotation periods, other types of interesting information have proved much more difficult to pin down. A light curve only measures the total hemispheric spot coverage at each given time, and this information is very degenerate in the parameters we would like to learn about. To understand the scope of this problem, the limitations it poses, and the sort of information that can still be extracted, we have modeled more than 100,000 cases with a systematically varied set of parameters. Our work shows that it may not be possible to obtain reliable information on stellar differential rotation in most cases. Spot lifetimes are somewhat more accessible, but the methods that have been tried so far need refinement. What appear to be stellar activity cycles can have other causes. The "single/double" nature of light curves sometimes deeply confuses half/full rotation periods, but also provides a new useful diagnostic. We discuss a set of useful metrics for precision light curves, and their distributions as a function of the parameters of interest. All these issues become worse as the number of rotation periods observed becomes smaller, making K2 and TESS light curves increasingly difficult to mine for reliable starspot information.

The 6-Dimensional Structure of an Expanded Census of the Taurus Star Forming Region

Daniel Krolikowski; Adam Kraus; Aaron Rizzuto; Benjamin Tofflemire

UT Austin

To understand the distinct stellar populations that comprise our galaxy, it is necessary to understand the environments in which stars are born. We can address outstanding questions in star formation, including the IMF and the relative importance of different spatial and temporal modes of star formation, by surveying star-forming regions and characterizing their stellar populations. The Taurus-Auriga star-forming complex is one of the most comprehensively studied regions of star formation in the Milky Way. The census of Taurus members has been built over the last eighty years, but questions remain as to its completeness. In particular, the discovery of a distributed stellar population at large distance from the central molecular clouds has further drawn into question the completeness of the census and the broader star formation history of the Milky Way in its vicinity. We present an expanded and inclusive census of the Taurus region, including candidate members throughout the region from past studies and an ongoing survey for new members using Gaia and the Tull spectrograph on the 2.7-m telescope at McDonald Observatory. We subdivide the census into groups based on their 3D galactic positions, and incorporate Gaia covariances into the subgroup modeling. Only in the era of Gaia can we study the detailed spatial and kinematic structure of star-forming regions to such high precision, provided we have equally precise radial velocities. With this Taurus census that is the most expansive to date, we determine the relative ages and kinematics of different subgroups in the region, and use this information to determine the star formation history of the region. We also highlight two subgroups in Taurus that contain planet hosting stars, and use those stellar populations to best determine the properties of these two planet hosts, K2-284 and V1298 Tau.

Fundamental Properties and Atmospheric Composition of Ultracool Dwarfs from Near- through Mid-infrared Spectrophotometr

Genaro Suarez; Stanimir Metchev

University of Western Ontario

We present an updated, accurate characterization of L and T dwarfs by comparing near- and mid-infrared spectrophotometry to atmospheric models. As a trial target we consider the T2.5 dwarf HN Peg B. We present a comprehensive SED of this dwarf that includes unpublished Spitzer IRS spectra and photometry. We complement the Spitzer data with published optical/near-infrared observations, and obtain an accurate bolometric luminosity. By fitting widely used atmospheric model spectra to the SED and the spectra, we obtain an accurate radius which, together with the bolometric luminosity, provide an evolutionary age and mass estimate of this very-low/planetary-mass brown dwarf companion. The best-fitting models show significant discrepancies in reproducing the marked strength of the CO absorption at 4.6 um. The feature is best reproduced by a BT-Settl model. A comparison among moderate-dispersion near-infrared spectra of HN Peg B and other young and old T2-T3 dwarfs shows that the 1.25-micron potassium lines show similar strengths regardless of an object's age. We conclude that the potassium lines, which are known to be sensitive to surface gravity in L- and earlier-type dwarfs, are not a good gravity (or age) indicator in early T dwarfs.

StePar/SteParSyn: two automatic codes to infer stellar atmospheric parameters

H. M. Tabernero (1); E. G. Marfil (2); D. Montes (3); J. I. González Hernández (4)

(1) Instituto de Astrofísica e Ciências do Espaço; (2) Universidad Complutense de Madrid; (3) Universidad Complutense de Madrid; (4) Instituto de Astrofísica de Canarias

StePar and SteParSyn are two codes designed to automatically infer the stellar atmospheric parameters of any FGKM-type star. StePar is a Python 3.X code designed to compute the stellar atmospheric parameters (Teff, log g, [Fe/H]) of FGK-type stars by means of the equivalent width (EW) method. This code has already been extensively tested in different spectroscopic studies of FGK-type stars with several spectrographs and against thousands of Gaia-ESO Survey UVES U580 spectra of late-type, low-mass stars. SteParSyn is yet another automatic code designed to infer the stellar atmospheric parameters of FGKM s tars using spectral synthesis alongside a Markov Chain Monte Carlo algorithm combined with a realistic modelling of the stellar noise by means of Gaussian Processes.

A Hierarchical Bayesian Framework for Predicting Stellar Radial Velocity Jitter

Jacob K. Luhn (1); Angie Wolfgang (2); Jason T. Wright (3); Howard Isaacson (4)

(1) Penn State University; (2) Penn State University; (3) Penn State University; (4) UC Berkeley

The detection of planets using the radial velocity (RV) method is hampered by astrophysical processes on the surfaces of stars. These processes induce a stochastic signal, or "jitter", which can drown out or even mimic the signal due to planets. Here we empirically investigate the RV jitter of more than 600 stars from the California Planet Search (CPS) sample with precise stellar properties. We show that stellar RV jitter ultimately tracks stellar evolution and that in general, stars evolve through different stages of RV jitter: younger main sequence stars are dominated by jitter that is driven by magnetic activity until they have aged and sufficiently spun down to the point where convectively-driven jitter (granulation, oscillations) becomes dominant. From this, we identify the "jitter minimum" - where activity-driven and convectively-driven components have similar amplitudes - for stars between 0.7 and 1.7 solar masses. We show that as a result of their more rapid evolution, more massive stars reach their jitter minimum later in their lifetime, in the subgiant or even giant phases. Finally, we use this framework to build a hierarchical Bayesian model to empirically fit each component of RV jitter. With this tool, one can predict the amplitudes of the various components of RV jitter across a wide range of stellar parameters, useful for prioritizing follow-up RV observations of planet candidates, such as those from TESS.

The Demographics of Wide Planetary-Mass and Substellar Companions and Their Circum(sub)stellar Disks through PSF Fitting of Spitzer/IRAC Archival Images

Raquel A. Martinez; Adam L. Kraus

The University of Texas at Austin

The last decade has seen the discovery of a growing population of planetary-mass and substellar companions (∼<20 M_{Jup}) to young stars which are often still in the star-forming regions where they formed. These objects have been found at wide separations (>100 AU) from their host stars, challenging existing models of both star and planet formation. Demographic trends with mass and separation should distinguish between these formation models.

The extensive Spitzer/IRAC data set of every major star-forming region and association within 300 pc has great potential to be mined for wide companions to stars. My survey is sensitive to companions with masses approaching that of Jupiter at orbital radii of a few hundred AU, discovering wide companions in their birth environments and revealing their circum(sub)stellar disks. I

will present a re-analysis of archival Spitzer/IRAC images of 9 stars (G0-M4.3) known to host faint planetary-mass and substellar companions (1.2”-12.3”) through previous high-contrast imaging observations at optical or near-IR wavelengths. I will report new mid-IR photometric measurements of this sample of wide-orbit companion systems, then discuss an automated companion search of all known young stars with existing Spitzer/IRAC data, concluding with my ongoing follow-up observations of candidate wide planetary-mass/substellar companion systems with ground-based telescopes and the outlook for future observations with space-based telescopes.

M dwarfs: from colours to luminosities

C. Cifuentes; J. A. Caballero; M. Cortés-Contreras

Centro de Astrobiología (CSIC–INTA), ESAC campus, Camino Bajo del Castillo s/n, E-28691 Villanueva de la Cañada, Madrid, Spain

In the quest for Earth-sized exoplanets, M dwarfs are stars of increasing interest during the last two decades. Their small sizes and masses as compared to our Sun make them specially suitable targets to look for the signatures of planetary companions. Despite being the most abundant stars in our Galaxy, it still exists large uncertainty about basic physical properties of M dwarfs. In particular, determining luminosities and effective temperatures —and from them masses and radii— is essential to characterise their planetary companions. In addition, how these parameters relate with colours provides with useful tools that help us gaining insight about the physical nature of the stars. CARMENES is a next-generation spectrograph, built and operated by the homonymous German-Spanish consortium of eleven institutions, which monitorises bright nearby M dwarfs using the radial velocity method. Carmencita, its input catalog, contains dozens of parameters for about 2200 M dwarfs, from M0.0 to M7.0, including photometric data in a broad range, from UV to mid-infrared. These photometric data, compiled and updated for 18 broadband filters, FUV, NUV, u', B_T, B, g', V_T, G, V, r', I', J, H, Ks, $W1$, $W2$, $W3$, $W4$, have made possible the determination of important stellar properties using Virtual Observatory tools.

The most energetic X-ray flares in the 2010s from the RS CVn type star GT Mus

Yohko Tsuboi (1); Wataru Iwakiri (2); Satoshi Nakahira (3); Yoshitomo Maeda (4); Keith Gendreau (5); Michael F. Corcoran (6); Kenji Hamaguchi (7); Zaven Arzoumanian (8); Craig B. Markwardt (9); Tatsuki Sato (10); Hiroki Kawai (11); Tatehiro Mihara (12); Megumi Shidatsu (13); Teruaki Enoto (14); Hitoshi Negoro (15); Motoko Serino (16)

(1) Chuo Univ.; (2) RIKEN; (3) JAXA/ISAS; (4) NASA/GSFC; (5) Ehime Univ.; (6) Nihon Univ.; (7) Aoyama Gakuin Univ.

The RS CVn type star GT Mus (HR4492, HD101379 + HD101380) was the most active star in the X-ray sky in the last decade in terms of the scale of recurrent energetic flares. MAXI (Monitor of All-sky X-ray Image) has caught eleven flares from GT Mus from 2009 August to 2017 August. The flare energies were 2–15$\sim\times\sim$10^{38}$\sim$erg, which are at the upper end of the stellar flare energies ever observed. One of the eleven flares was observed with NICER (Neutron star Interior Composition Explorer) on 2017 July 18 as a follow-up observation of MAXI detection. This flare was cooled quasistatically. Based on this cooling model, the flare loop length was 5.1$\sim\times\sim$10^{12}$\sim$cm (or 73 solar raius). This is three times larger than the stellar radius (1.7$\sim\times\sim$10^{12}$\sim$cm), which is not exceptionally huge one for GT Mus. The electron density was 6.2$\sim\times\sim$10^{9}$\sim$cm^{-3}. This is consistent with a

typical value of solar and stellar flares ($10^{10-12}\sim$cm^{-3}). The ratio of the cooling timescales between radiative cooling ($\tau_{\rm rad}$) and conductive cooling ($\tau_{\rm cond}$) is estimated as $\tau_{\rm rad}\sim=\sim0.1\tau_{\rm cond}$. Therefore, radiative cooling was dominant in this flare. Here, we review the GT Mus flares observed in the last decade (Sasaki et al. 2020 to be submitted).

Posters

Geomagnetically induced currents related to impulsive events at low latitudes.

Nguessan Kouassi; Vafi Doumbia; Boka Kouadio; Zie Tuo

Université Félix Houphouet Boigny Abidjan -Cote d' Ivoire

Intense space weather events (geomagnetic storms and sub-storms) are potential sources of electric induction within the Earth. Disruptions of technological equipments due to "Geomagnetically Induced Currents (GICs)" are experienced in the Scandinavian countries since mid XIXth century (Pulkkinen, 2003). Due to the harmful impacts of GICs on technological devices, the GICs have been mostly investigated at high latitudes (Pulkkinen et al., 2001a, 2001b, 2003, 2007). There are reports on GIC causing perturbation in technological structures in mid- and low-latitude (Ngwira et al., 2008; Torta et al., 2012, Trivedi et al., 2007). Due to these threats, we study the GICs at low latitudes namely in West Africa. In our study, we estimate the geoelectric field from the geomagnetic data and compare it to the measured geoelectric field. We note that our results are in good agreement with the measures. Then, we estimate the intensity of the GICs from the geoelectric field calculated on the one hand and on the other hand, from the measured geoelectric field.

He I 10830 transit observations of the hot gas giant HAT-P-10 b

P. Wilson Cauley (1); Seth Redfield (2); Evgenya Shkolnik (3); Antonija Oklopcic (4); Kevin France (5); Adam Jensen (6); Ilaria Carleo (7)

(1) University of Colorado Boulder; (2) Wesleyan University; (3) Arizona State University; (4) University of Amsterdam; (5) University of Colorado Boulder; (6) University of Nebraska Kearney; (7) Wesleyan University

Atomic transitions can be used to probe the extended layers of exoplanet atmospheres, particularly hot planets which are puffed up due to the extreme amount of energy deposited in the atmosphere. Recently, the helium triplet transition at 10830 angstroms has been revived as an excellent tracer of exoplanet thermospheres. He I 10830 angstroms is also a useful chromosphere diagnostic in active stars. where it is seen in absorption due to the In this poster we present the results of He I 10830 angstrom transit observations of the hot gas giant HAT-P-10 b.

Determination of Stellar Parameters of the TIGRE sample

Ilse A. Aguilar Segoviano; Dennis Jack; Klaus Peter Schröder

University of Guanajuato

A star is a gas sphere where the inward pull of gravity is balanced by the tendency to expand due to the internal gas pressure gradient (see De Boer, 2012), this is the visible part of the star we call Atmosphere. By studying the atmosphere of a star we can obtain important information of its interior; since it is the transition zone from the interior of the star to the interstellar medium. The energy inside the star flows outward as radiation. The observations show that radiative transfer plays an important role in the model of stellar atmospheres, since it is possible to determine some stellar parameters. The TIGRE robotic telescope (located in the city of Guanajuato, Gto; Mexico) which is part of the bilateral project between the University of Hamburg (Germany), University of Guanajuato (Mexico) and the University of Liège (Belgium), observed (between September 2017 - April 2018) samples of stars that did not have a spectrum, and which reached their zenith in December 2017, also fulfilled the following criteria. • S&N approximately 40 to 50 • The parallax is reported in GAIA • The radial velocity has not been reported in SIMBAD • The B-V color index is greater than 0.3. According to the established criteria, the final sample was of 130 stars. From this sample, the first 30 stars were observed during the period from September 2017 to April of 2018 and 3 of these were found to be binary by analyzing changes in their radial velocity. From the study of the sample of these 30 stars, we want to obtain the physical parameters and classify them in the Hertzprung Russell Diagram of spectral classification with evolution tracks codes. The parameters that will be obtained from this sample of stars are the effective temperature, surface gravity and metallicity. These parameters will be obtained from the program iSpec. iSpec is a tool for the treatment and analysis of stellar spectra. iSpec is able to determine atmospheric parameters (i.e. effective temperature, gravity of surface, metallicity, micro / macro-turbulence, rotation) and individual chemical abundances for the stars of types A, F, G, K and M by the Synthetic spectra adjustment method in which the observed spectrum is compared with the theoretical spectra that is synthesized or interpolated from precalculated grids.

Stellar Motion Detector (SMDET) : a citizen science tool using neural networks in search of moving objects in WISE images cubes.

Dan Caselden (1); Guillaume Colin (2); Lindsay Lack (3); Federico Marocco (4); J Davy Kirkpatrick (5); Aaron Meisner. (6)

(1) Gigamon Applied Threat Research; (2) Service de pneumologie, hôpital de Pau; (3) Backyard Worls collaboration; (4) Jet Propulsion Laboratory, California Institute of Technology; (5) IPAC; (6) NSF's National Optical-Infrared Astronomy Research Laboratory

Built by citizen scientists, SMDET applies a custom convolutional recurrent neural network to segment and classify cubes of astronomical images in search of moving objects. This is the first deep learning approach applied to object discovery in unWISE images.

METHOD : It is trained on synthetic moving objects added to unWISE time-resolved coadds. We iteratively apply SMDET to portions of the unWISE image set, manually label the results, and retrain the model in hopes of improving model accuracy and discovering new high proper motion objects. Despite the selectivity of brown dwarf candidates by red WISE W1 - W2 color, SMDET is trained to leverage motion information with synthetic objects of a normal color distribution. This enables sensitivity to peculiar objects missed in previous color-informed searches such as sub dwarfs, and allow us to expand our training set by adding nearby white dwarfs which exhibit substantial motion and have faint WISE magnitudes. Although trained on synthetic data, SMDET successfully detects real moving brown and white dwarfs.

RESULTS : In early models 86% of the very small (n = 35) sample of known fast and faint objects would be recovered with manual review of <55,000 samples. Each new classification is currently refining the model and improving performance.

CONCLUSION : SMDET is a promising tool for detecting moving objects. We hope to apply it to other moving object scenarios, and explore performance with other image sets. This work is an

example of the usefulness that citizen science can have with astronomical research, whether for creating new tools for humans or training AI-powered ones.

The role of flares and coronal-mass-ejections on the habitability of M-star planets.

Eike W. Guenther (1); Priscilla Muheki (2)

(1) Thüringer Landessternwarte Tautenburg; (2) Mbarara University of Science and Technology

The long-term goal of exoplanet research is to find out whether Earth-twins are common, or rare. The focus has recently shifted from planets of solar-like stars to planets of M-stars. The reason is, that it is easier to detect low-mass planets of low-mass stars. Of particular interest are, of course, planets in the so-called habitable zone. A number of potentially habitable planets have already been identified. One important aspect of habitability is the planetary atmosphere. Recent theoretical studies have shown that the potential habitability depends on the amount of X-ray and UV (XUV)-radiation planets receive from their host stars. If the stars are too inactive, the planets may keep their initial Hydrogen atmosphere. If the stars are too active, the planets become more like Venus rather than Earth. A high level of XUV-radiation can also sterilize a planet that would otherwise be habitable. Since flares and coronal-mass-ejections (CMEs) both affect the habitability of planets, we have to determine their rates on M-stars. Because the main activity phase of stars is at young age, we have to study the activity of young M-stars. For our study, we have thus selected the Upper Sco region, which has an age of 5-10 Myr. At this age planets have just formed are now exposed to a high level of XUV-radiation. A Neptune-like planet has already been found in this region. We have obtained UVES+FLAMES spectra to determine the stellar parameters, and analysed the light-curves from the Kepler-K2 mission. In total, we have detected more than 800 flares, and derived the cumulative frequency distribution for them. In a second study, we have spectroscopically monitored active M-stars to constrain the rate of CMEs. It appears that the CME-to-flare ratio of M-stars is quite different from that of the Sun. It is thus doubtful whether it is possible to use scaled-up solar flare and CME-models for M-stars.

Simultaneous magnetic field and radial velocity measurement via Least-Squares Deconvolution

Florian Lienhard; Annelies Mortier

University of Cambridge

The validation and recovery of periodic signals in radial velocity data, especially low amplitude signals, is being complicated by the inherent stellar variations due to stellar activity. Using the time-series of high-resolution HARPS-N spectra of stars as well as the Sun, I aim to develop a new least-squares deconvolution method to determine at the same time a precise radial velocity and an independent measurement of the instantaneous line-of-sight magnetic flux on the visible stellar hemisphere. I will show the first results of this new extraction method and compare with current methods.

The importance of precise stellar parameters for determining the long-term habitability of exoplanets: Applications for direct imaging target selection

Noah W. Tuchow; Jason T. Wright; James F. Kasting

Pennsylvania State University

For the next generation of exoplanet direct imaging missions, it is of the utmost importance to select and prioritize target stars in order to maximize the number Earth-like exoplanets that can have their atmospheric compositions characterized, with the ultimate goal of detecting potential biosignatures. We argue that target selection for future direct imaging missions, such as HabEx and LUVOIR, should not only focus on imaging planets that currently reside in the habitable zones of their stars, but also favor planets that have remained in the habitable zone for an extended duration. We have designed prioritization metrics for the long-term habitability of exoplanets around a potential host star. Modelling the temperature and luminosity evolution of target stars, one can assess their potential to support long-term habitability, regardless of whether they host known planets. Whether a star is likely to host older habitable planets, depends on whether 'cold-start' planets, forming outside the outer edge of the habitable zone and entering it later in a star's evolution, can become habitable. For example cases of the stars 55 Cancri and Theta Cygni, we show that assumptions about the habitability of 'cold-starts' and the period distribution of exoplanets change which populations of stars are favored in terms of long-term habitability. To accurately assess the long-term habitability around a star, one needs precisely determined properties such as masses, ages, and metallicities, and we argue that determining these stellar properties should be a priority for target selection.

Convective overshooting in hydrodynamic simulations of the F-type eclipsing binary BW Aquarii

Jane Pratt (1); Mary Geer Dethero (2); Isabelle Baraffe (3); MUSIC Team (4)

(1) Georgia State University; (2) Georgia State University; (3) University of Exeter

Using a realistic stratification in density, temperature, and luminosity obtained from the MESA models of Lester and Gies (2018), we produce global multi-dimensional hydrodynamic simulations with the MUSIC code. These MESA models were produced as a best match to the observational data for BW Aqr, but the models fail to produce the observed properties of the stars and predict the two stars to be the same age; improvement to stellar evolution modeling is necessary to understand this particular binary pair, as well as the wealth of new stellar observations available from recent space missions. In this contribution we study the properties of non-local stellar convection and convective overshooting in both the primary and secondary star in the eclipsing binary, near the beginning of the red giant branch and the first dredge-up. Using our recent enhanced diffusion model for convective overshooting and penetration (Pratt et al 2017) proposed for one-dimensional stellar evolution calculations, we compare the amount of mixing due to convective overshooting between these stars.

New Constraints on M Dwarf Winds from the Hubble Space Telescope

Brian E. Wood (1); Hans-Reinhard Mueller (2)

(1) Naval Research Laboratory; (2) Dartmouth College

New observational constraints on stellar winds and astrospheres have recently become available from the Hubble Space Telescope, particularly with regards to the winds of M dwarf stars. Interest in M dwarf winds is currently very high due to the discovery of a number of Earth-like planets in the habitable zones around M dwarf stars, leading to substantial interest in the stellar environments for these planets and their atmospheres. Coronal winds emanating from solar-like stars can only be detected via the hydrogen Lyman-alpha absorption created in the wind/ISM interaction region. A spectroscopic survey of the Lyman-alpha lines of 9 nearby M dwarfs has recently been completed, with 6 of the targets yielding successful detection of the astrospheric absorption signature. Analysis is still underway, but the study clearly shows that most M dwarfs have winds significantly weaker than that of the Sun.

The Gaia binary star orbit revolution

Logan A Pearce (1); Adam L Kraus (2); Trent J Dupuy (3); Andrew W Mann (4); Elisabeth R Newton (5); Benjamin M Tofflemire (6); Andrew W Vanderburg (7)

(1) Steward Observatory, University of Arizona; (2) University of Texas; (3) Gemini Observatory North; (4) University of North Carolina; (5) University of Texas; (6) University of Texas; (7)

The orbital elements of planets, low mass companions, and binary stars, particularly eccentricity and inclination, encode angular momentum information about these systems. The magnitude and (mis)alignment of angular momentum vectors among stars, disks, and planets probe the complex dynamical processes guiding their formation and evolution. Trends in orbital parameters among population groups are thus a vital clue to understanding how planets and stars form and evolve. Wide stellar binary systems are relatively easy to observe astrometrically, but their comparatively long orbital periods require long observational time periods to place any scientifically useful limits on orbital elements. The precision of Gaia astrometry for the individual resolved components of binary systems can offer a promising alternative. We present our demonstration on the use of precise Gaia astrometry (positions and proper motions) to provide better constraint on orbital parameters for wide stellar binaries than long time series astrometric monitoring for some systems, and enable constraint of orbital parameters for other systems for which time series astrometry is not available. We also show how future Gaia data releases will improve orbit determinations dramatically by providing precise relative radial velocity and acceleration measurements for many binary systems. The precision and ease of access to Gaia measurements is a dramatic improvement in binary orbit monitoring compared to historical orbit determinations requiring long astrometric monitoring of one system at a time. The study of star and planet formation is being revolutionized by the promise of Gaia.

Radio eclipses of exoplanets by the winds of their host stars

Robert D. Kavanagh; Aline A. Vidotto

School of Physics, Trinity College Dublin, The University of Dublin, Dublin 2, D02 PN40, Ireland

Up until very recently, the search for exoplanetary radio emission had resulted in no conclusive detections to date. Various explanations for this have been proposed, from the observed frequency range, telescope sensitivity, to beaming of the emission. Exoplanets can orbit through the radio photosphere of the wind of the host star, a region that is optically thick at a specific frequency, for a large fraction of their orbits. As a result, radio emission originating from the planet could be absorbed or ‘eclipsed’ by the wind of the host star. Here we investigate how the properties of the stellar wind and orbital parameters affect the fraction of the orbit where the planet is eclipsed by the stellar wind. We show that planets orbiting stars with low density winds are more favourable

for detection in the radio. In terms of the orbital parameters, emission from transiting planets can escape the stellar wind easiest. We apply our model to the tau Boo planetary system, and show that observing the fraction of the planet's orbit where it is eclipsed by the wind of the host star could be used to constrain the properties of the stellar wind. However, our model developed would need to be used in conjunction with a separate method to disentangle the mass-loss rate and temperature of the stellar wind.

Investigations of Flares in VB10 using high resolution infrared spectroscopy

Shubham Kanodia; Lawrence Ramsey; Helen Baran; HPF team

Department of Astronomy, Pennsylvania State University, Center for Exoplanets and Habitable Worlds, Pennsylvania State University

Flare activity in late M stars remains an interesting topic since there is as yet no well tested model of how these convective stars generate the magnetic field that underlie activity such as flares, and the rate and strengths of the flare can impact the evolution of the atmospheres of planets orbiting them We present observations of two flares observed on the M8 star VB10 with the Habitable zone Planet Finder (HPF) on the Hobby Eberly Telescope. HPF is designed to be very stable for precision radial velocities but its NIR coverage (810 –1280 nm) and queue scheduled operations allow us to obtain multiple observations to analyze the properties of the flares. A combination of the 10 m telescope aperture with the nondestructive read readout with our H2RG enables us to obtain a time resolution of $\sim$ minutes on this late type M dwarf, which helps us resolve the evolution of the flare. We present our analysis of the Ca II infrared triple lines as well as Pa γ and δ to place constraints on the time behavior and physical conditions of the emitting material.

Asterospheric Fields of Cool Stars and their Impact on Exoplanetary Environments

David Alexander (1); Frank Toffoletto (2); Alison Farrish (3); Anthony Sciola (4); Marc DeRosa (5)

(1) Rice University; (2) Rice University; (3) Rice University; (4) Rice University; (5) Lockheed Martin Advanced Technology Center

We apply a solar-derived photospheric magnetic flux transport model and a magnetically-driven stellar coronal heating model to explore the asterospheric magnetic fields of a range of active cool stars and the subsequent effect on any planets present within the system. We discuss how the stellar activity influences the large-scale coronal magnetic field and the consequent EUV and X-ray emission. Finally, we consider the response of the planetary magnetosphere and ionosphere to the stellar activity with an emphasis on the enhanced ionospheric currents resulting from the significantly larger EUV and X-ray fluxes in more active stars.

First results from POKEMON

Catherine Clark (1); Gerard van Belle (2); Elliott Horch (3); Kaspar von Braun (4); David Ciardi (5); Frederick Hahne (6); Joe Llama (7); Jennifer Winters (8)

(1) Northern Arizona University, Lowell Observatory; (2) Lowell Observatory; (3) Southern Connecticut State University; (4) Lowell Observatory; (5) Caltech/IPAC; (6) Southern Connecticut State University; (7) Lowell Observatory; (8) Harvard-Smithsonian Center for Astrophysics

We present 29 new companions to nearby M-dwarfs detected throughout the POKEMON speckle survey, including the 5 objects that have been confirmed with second epoch observations. We obtained high-resolution images with DSSI on the 4.3m Lowell Discovery Telescope located in Happy Jack, AZ, and with NESSI on the 3.5m WIYN at Kitt Peak National Observatory located in Tucson, AZ. Because DSSI and NESSI observe simultaneously at two wavelengths, we obtain relative photometry, and are able to calculate temperatures and luminosities for the new companions. We also calculate the magnitude difference in these systems, resulting in spectral types for the new companions. Future work will present the full sample of M-dwarfs from the POKEMON survey, but these objects themselves represent a $\sim 8\%$ increase in known companions to our low-mass neighbors.

Twinkle, twinkle, little star: unravelling the stellar atmospheric parameters of FGKM-type stars from CARMENES spectra

Emilio Marfil (1); Hugo M. Tabernero (2); David Montes (3); J. A. Caballero (4); F. J. Lázaro-Barrasa (5); J. I. González Hernández (6); Maritza G. Soto (7); Evangelos Nagel (8); Adrian Kaminski (9); Sandra V. Jeffers (10); Ansgar Reiners (11); Ignasi Ribas (12); Andreas Quirrenbach (13); Pedro J. Amado (14); Vera M. Passegger (15); Andreas Schweitzer (16); Florian F. Bauer (17); Miriam Cortés-Contreras (18); Stefan Dreizler (19); Martin Kürster (20); Marina Lafarga (21); Juan Carlos Morales (22); Matthias Zechmeister (23)

(1) Universidad Complutense de Madrid & IPARCOS-UCM; (2) Universidade do Porto; (3) Universidad Complutense de Madrid & IPARCOS-UCM; (4) Centro de Astrobiología (CSIC-INTA); (5) Universidad Complutense de Madrid & IPARCOS-UCM; (6) Instituto de Astrofísica de Canarias; (7) Queen Mary, University of London; (8) Hamburger Sternwarte, Universität Hamburg; (9) Landessternwarte, Zentrum für Astronomie der Universität Heidelberg; (10) Institut für Astrophysik, Georg-August-Universität-Göttingen; (11) Institut für Astrophysik, Georg-August-Universität-Göttingen; (12) Institut de Ciències de l'Espai (CSIC) & Institut d'Estudis Espacials de Catalunya (IEEC); (13) Landessternwarte, Zentrum für Astronomie der Universität Heidelberg; (14) Instituto de Astrofísica de Andalucía; (15) Hamburger Sternwarte, Universität Hamburg; (16) Hamburger Sternwarte, Universität Hamburg; (17) Instituto de Astrofísica de Andalucía; (18) Centro de Astrobiología (CSIC-INTA); (19) Institut für Astrophysik, Georg-August-Universität-Göttingen; (20) Max-Planck-Institut für Astronomie; (21) Institut de Ciències de l'Espai (CSIC) & Institut d'Estudis Espacials de Catalunya (IEEC); (22) Institut de Ciències de l'Espai (CSIC) & Institut d'Estudis Espacials de Catalunya (IEEC); (23) Institut für Astrophysik, Georg-August-Universität-Göttingen

The accurate computation of the stellar atmospheric parameters of FGKM-type stars from high-resolution spectra, namely $T_{\rm eff}$, $\log g$, and [M/H], lays the cornerstone not only for our current understanding of the Milky Way but also for recent planet formation theories. In this talk we aim to review the equivalent width (EW) method and the spectral synthesis technique to derive stellar atmospheric parameters of FGKM-type stars in light of the optical and near-infrared spectra obtained with CARMENES, the high-resolution, double-channel spectrograph installed at the 3.5 m telescope at Calar Alto observatory. On the one hand, we will discuss the results for 65 FGK-type stars observed with CARMENES and analysed with the StePar code, a Python implementation of the EW method, placing special emphasis on the impact of the near-infrared wavelength region on the parameter computations. On the other hand, we will also highlight the stellar atmospheric parameters

obtained for the CARMENES GTO M dwarfs computed by means of the spectral synthesis technique as implemented in the SteParSyn code.

Measuring the tidal interaction footprint on stellar magnetic activity in star-planet systems

Nikoleta Ilic; Katja Poppenhaeger

Leibniz Institut fuer Astrophysik Potsdam, Germany

It is an open question to what degree planets influence the (magnetic) evolution of their host star. We investigate the tidal interaction in star-planet systems, which reside in binary or multiple stellar systems, by comparing the magnetic activity level of the planet host with the stellar companion's activity.
As a star ages and evolves, its rotational rate decreases and the star spins down. The increase in stellar rotational period results from the angular momentum loss due to the process called magnetic braking. This is the usual 'spin-down' scenario for singular stars and stars without planets.
In star-planet systems, the possibility of halting the decrease or even increasing the rotational rate of a star due to tidal interaction with its planet(s) exists. This tidal 'spin-up' can be traced by an enhanced magnetic activity since a faster rotating star is expected to be more magnetically active. The difficulty here is estimating if the observed magnetic activity level of the star is higher due to the tidal interaction with the planet or due to the relatively young age, when the process of magnetic braking is still undergoing. Our solution for this is to invoke a reference star that does not host a planet and that has the same age as the planet-hosting star. Therefore, we analyse wide binary and multiple stellar systems that have a planet-hosting star and use its coeval stellar companion as a proxy for the expected magnetic activity level. We have a sample of 37 stellar systems, observed in X-rays with XMM Newton and Chandra, for which we evaluate the component' X-ray luminosity. We expect that the enhanced magnetic activity of the planet host leads to a hotter corona and hence a brighter X-ray source when compared to its stellar companion, if the enhancement is due to tidal interaction.
With this approach, we will be able to determine if the tidal 'spin-up' process can leave an observable footprint on planet-hosting stars and which star-planet system configuration is prone to significantly changing the activity level of the star.

The loci of megaflares on the surfaces of fully convective stars

Ekaterina Ilin (1); Sarah J. Schmidt (2); Katja Poppenhäger (3); Silva Järvinen (4); Ilya Ilyin (5); Mahmoud Oshagh (6)

(1) Leibniz Institute for Astrophysics Potsdam (AIP); (2) Leibniz Institute for Astrophysics Potsdam (AIP); (3) Leibniz Institute for Astrophysics Potsdam (AIP); (4) Leibniz Institute for Astrophysics Potsdam (AIP); (5) Leibniz Institute for Astrophysics Potsdam (AIP); (6) Instituto de Astrofisica de Canarias

Small, fully convective stars produce intense white light flares that indicate strong stellar magnetic fields. However, how these fields are produced is still unclear, since the solar-like magnetic dynamo requires a star to have a radiative core which is missing in these stars, and alternative dynamo models still struggle with reproducing the observables of fully convective stars. Using Kepler and TESS light curves, we discovered long-duration flares on fully convective, fast rotating (P<12h) stars. These flares last for several stellar rotation periods so that their loci repeatedly move in and out of

view. The observed light curves are distinctly modulated and provide the unique possibility to infer the latitudes where the flares occurred. We demonstrate that the observed flare light curves can be adequately described by rotational modulation of bright (10 000 K) photospheric spots. In some cases, the degeneracy with rotational inclination can be broken by combining measurements of rotational line broadening with the photometric rotation period. For these stars, we inferred the latitudes of the spots, and the flares' properties. The results provide important constraints for dynamo models of fully convective stars.

Total lunar eclipse January 2019: observing the Earth as a transiting planet in Stokes IQUV

K. G. Strassmeier (1); I. Ilyin (2); E. Keles (3); M. Mallonn (4); A. Jarvinen (5); M. Weber (6); F. Mackebrandt (7); J. M. Hill (8)

(1) Leibniz-Institute for Astrophysics Potsdam (AIP); (2) University of Göttingen; (3) Large Binocular Telescope Observatory

We present high-resolution time-series spectroscopy and polarimetry of the January 21st, 2019 total lunar eclipse. The exposure meter of our spectrograph was used as a photon counting photometer in white light and recorded a 10.75 magnitude drop of brightness during totality. The intensity spectra during umbral eclipse are dominated by strong O2 and H2O atmospheric flux absorption otherwise not seen as strong during penumbral eclipse or outside eclipse. Beside excess molecular absorption, our umbral spectra also show excess atomic absorption in the line cores of the singly-ionized Ca II infrared triplet at a 8–14 sigma level as well as in the KI line at 7699Å at even 17sigma. From our deep penumbral spectra, we additionally identify excess absorption from the neutral Na D lines (at 14 sigma significance), several neutral Mn lines (5–11sigma), and singly-ionized Ba (7–12sigma). The detections of the latter two elements, Mn and Ba, are due to an untypical solar center-to-limb effect rather than Earth's atmosphere.

Chromospheric modeling for CARMENES targets with PHOENIX

Dominik Hintz; Birgit Fuhrmeister; Stefan Czesla; Jürgen H. M. M. Schmitt; CARMENES Consortium

Hamburger Sternwarte, University of Hamburg

Stellar activity is ubiquitous in M dwarfs. It is a notorious nuisance for high-precision radial velocity planet searches and produces hazardous environments for the atmospheres of planets orbiting these stars. The characterization of the temperature structure of the chromosphere is imperative to understand the upper atmosphere and its impact on the observed spectra of late-type stars. Using the stellar atmosphere code PHOENIX, we constructed a set of 1D chromospheric models with empirical temperature structure to simultaneously fit the lines of Na I D_2, Hα, and the bluest Ca II infrared triplet line in a sample of 50 M2-3 dwarfs observed by the CARMENES (Calar Alto high-Resolution search for M dwarfs with Exoearths with Near-infrared and optical Échelle Spectrographs) spectrograph. For the inactive stars, we find good agreement with individual models with a temperature structure corresponding to modified VAL C models. Reproducing the chromospheric lines of the active stars requires linear combinations of an inactive and an active model component, from which we also obtain surface filling factors for the respective components. For stars observed at different activity levels, our modeling yields a clear correlation between the surface filling factor of the active model component and the activity level. Although the models are not optimized for the He

I infrared line at 10 830 , the best-fit models also give an adequate prediction of the respective line absorption for most stars of the stellar sample. Furthermore, we performed a detailed analysis of the He I infrared line behavior in prescribed model configurations with different levels of activity. The behavior of the He I infrared line strengths as a function of the respective EUV radiation show the need of the mechanism of photoionization and recombination to form the line for inactive models, while collisions start to contribute for more active models.

Characterization of M Dwarfs via Sparse Approximation

Yohei Koizumi; Teruyuki Hirano; Bun'ei Sato

Tokyo Institute of Technology

M dwarfs have been gathering attention as promising targets to search for Earth-like planets in habitable zones. Several groups are conducting planet surveys around M dwarfs, and in those surveys understanding stellar properties is essentially important because planet properties, such as mass, radius, and habitability, heavily relies on their host stars' properties. Some of traditional stellar characterizations are based on synthetic model spectra. However, current model spectra of low-mass stars suffer from incomplete understandings of stellar atmospheric structure and molecular opacity. Recently, data-driven method provides model-independent stellar parameters. One of such techniques, sparse approximation, is a supervised learning method which deals with sparse solutions for systems of linear equations, and it can extract the most informative set of spectral features from a large amount of features. We have developed a stellar-model independent technique to estimate stellar properties, such as effective temperature and metallicity using sparse modeling. We present the result of our analysis which utilize optical low resolution spectra.

Star Formation History of Sagittarius Dwarf Irregular Galaxy Through Long Period Variable Stars.

Shahrzad Dehghani (1); Tahere Parto (2); Atefeh Javadi (3); Jacco Th. van Loon (4); Elham Saremi (5); Habib Khosroshahi (6); Mohammad Taghi Mirtorabi (7)

(1) Bonn-Cologne Graduate School of Physics and Astronomy, BCGS, Univeristy of Cologne, Germany; (2) Physics Department, Alzahra University, Iran; (3) School of Astronomy, Institute for Research in Fundamental Sciences (IPM), Iran; (4) Astrophysics Group, Lennard-Jones Laboratories, Keele University, Uk; (5) School of Astronomy, Institute for Research in Fundamental Sciences (IPM), Iran; (6) School of Astronomy, Institute for Research in Fundamental Sciences (IPM), Iran; (7) Physics Department, Alzahra University, Iran.

Our research mainly focuses to obtain the Star Formation History (SFH) of Sagittarius Dwarf Irregular Galaxy (SagDIG). We follow the method applied by Javadi (Javadi et al. 2011a, MNRAS, 411, 263 (Paper I), Javadi et al. 2017, MNRAS, 464, 2103 (Paper V)) in order to identify the Long Period Variable stars (LPVs) such as the Asymptotic Giant Branch stars (AGBs) and red supergiants (RSGs) in SagDIG. The main reason behind these identifications is that we can evaluate the relation between luminosity and birth mass of these most evolved stars which leads to determining the SFH. Images of Sagittarius Dwarf Irregular Galaxy were obtained by us over the interval Jun 2016 - October 2017 using INT telescope in i and V-band. The calculation of the instrumental magnitude of stars and variability analysis is done by utilization of DAOPHOT/ ALLFRAME/ NEWTRIAL procedures in the DAOPHOT II package (Stetson P. B., 1996, PASP, 108, 851). The various types of galaxies consist of a majority of Andromeda's satellites and isolated galaxies in Local Group come

under the scrutiny of our team to investigate SFH of these galaxies by identification of LPVs. This project is a part of this comprehensive survey.

Later, in the next project, we model the spectral energy distribution and mass-loss rate of these evolved stars. Due to a lack of sufficient information about the amount of dust produced by stars in low-metallicity galaxies, investigation of the isolated SagDIG can lead to extended knowledge about dwarf irregular galaxies. We will investigate the total amount of mass entering interstellar space and the type of matter that enters these environments. The study will allow us to examine the chemical evolution of SagDIG as well as the amount of dust produced by stars in gas-rich and low-metallicity environments.

Investigating the Mineralogy of Clouds in Brown Dwarf Atmospheres

Caroline Morley

University of Texas at Austin

Brown dwarfs, substellar objects not massive enough to fuse hydrogen, have cool atmospheres with the temperatures of giant planets.Their atmospheres are cool enough to form clouds and their temperature determines which species condense. Thick layers of dust, likely made of silicates, blanket L dwarf atmospheres, limiting the depths probed by spectra; these clouds clear dramatically at the L/T transition. Cloud chemistry and microphysics is challenging to model from first principles; clouds clearly form, but the specific species that condense are not well-constrained from theory. This uncertainty is a major barrier to understanding exoplanet atmospheres. The next key step in understanding these clouds is to empirically determine which clouds form using mid-infrared spectroscopy to identify mineral species. Currently there is tentative evidence from Spitzer that silicate features are present in L dwarf spectra. JWST could allow us to measure these features in many L dwarfs. Before these observations are made, we need to understand in detail at what wavelengths the strongest cloud absorption features will be, and predict which objects will have the largest amplitude signals. We present our results exploring the impact of individual cloud species, including how particle sizes and cloud mineralogy change spectral features. We investigate which objects are most ideal to observe, exploring a range of temperatures and surface gravities. We find that silicate and corundum clouds have a strong cloud absorption feature for small particle sizes (<1 um). Silicate clouds strongly absorb at 10 um while corundum absorbs at 11.5 um. We simulate time-series observations with the MIRI instrument on JWST for a range of nearby, cloudy, and photometrically variable brown dwarfs. Our predictions suggest that with JWST, by measuring spectroscopic variability inside and outside a mineral feature (eg. the silicate feature), we can uniquely identify a range of clouds species. Mid-infrared time-series spectroscopy can therefore be used to empirically constrain the complex cloud condensation sequence in brown dwarf atmospheres.

Updated constraints on the abundances of ultracool members of Omega Centauri and predictions for brown dwarfs using a new grid of model atmospheres and interiors

Roman Gerasimov (1); Adam Burgasser (2); Derek Homeier (3); Jon Rees (4); Andrea Bellini (5); Luigi R. Bedin (6); Aaron Dotter (7); Mattia Libralato (8); Antonino Milone (9)

(1) University of California San Diego; (2) University of California San Diego; (3) Universität Heidelberg; (4) New Mexico State University; (5) Space Telescope Science Institute; (6) Istituto Nazionale di Astrofisica; (7) Center for Astrophysics | Harvard & Smithsonian; (8) Space Telescope Science Institute; (9) Università di Padova

The coeval and co-evolving members of globular clusters serve as stellar astrophysics laboratories, as otherwise inaccessible parameters such as age and composition are often restricted within the cluster and may be inferred from its colour-magnitude diagrams. Until recently, the typically large distances of globular clusters confined such studies to their most massive members. Now, the promise of highly sensitive ground- and space-based facilities will extend the reach of these studies into the substellar regime. We are investigating the elemental abundances of stars in one of the closest and most well-studied globular clusters, ω Centauri, using a new grid of synthetic spectra and colour-magnitude diagrams produced with a custom combination of ATLAS and PHOENIX 15 model atmospheres and the MESA evolutionary code. To our knowledge, these new models yield the best agreement with HST infrared photometry, and emphasize the importance of atmosphere-interior coupling at low effective temperatures. We find that α-elements enhancement in the abundances of ultracool dwarfs plays a key role in determining their observable characteristics. Our models provide greater consistency in the colour-magnitude diagram between the most massive and least massive stars on the main sequence, although we find that the best-fit metallicity for the ultracool dwarfs is somewhat higher. Comprehensive treatment of molecules and clouds by the Settling formalism of the PHOENIX code enables us to assess the effects of gravity and composition on the formation of cloud layers. This allows us to extend model isochrones beyond the limit of existing photometric data. We make quantitative predictions for the colours and magnitudes of ω Centauri substellar population, which will inform observing strategies for future studies with JWST, TMT and GMT. We also highlight other potential uses of our modelling framework in studies of low-mass members of dwarf satellite galaxies and detailed composition analysis of local ultracool dwarfs.

Dynamical age of the beta Pictoris moving group

Núria Miret-Roig (1); Phillip A.B. Galli (2); Hervé Bouy (3); David Barrado (4); Javier Olivares (5); Teresa Antoja (6); Mercè Romero-Gómez (7); Wolfgang Brandner (8)

(1) Laboratoire d'astrophysique de Bordeaux; (2) Laboratoire d'astrophysique de Bordeaux; (3) Laboratoire d'astrophysique de Bordeaux; (4) Centro de Astrobiología (CSIC-INTA); (5) Laboratoire d'astrophysique de Bordeaux; (6) Universitat de Barcelona (IEEC-UB); (7) Universitat de Barcelona (IEEC-UB); (8) Max Planck Institute for Astronomy

Ages are one of the most fundamental parameters in astrophysics and yet they remain extremely difficult to determine. The different methods used, based on different astrophysical models, and the lack of a universal age scale result in discrepancies up to 50%. The importance of dynamical ages for bound or unbound systems such as moving groups or associations is that they provide an independent measure from the usual isochronal ages which rely on evolutionary models or the lithium age which is only well established for a limited range of ages. In this work, we combine the extremely precise Gaia DR2 astrometry with ground-based radial velocities measured in a homogeneous manner to obtain a dynamical age of the beta Pictoris moving group, getting around the main limitations of this methodology, namely, the membership uncertainties and the assumption of a Galactic potential. We use an updated version of an existing algorithm which provides a better estimate of the age uncertainties, and we compare our results with other age-dating techniques.

Predicted Hydrogen Emissions from Accretion and Outflow in T Tauri Stars

Tom J. G. Wilson; Sean Matt; Tim Harries for the AWESoMeStars Team

University of Exeter

Accretion and outflows in T Tauri stars control the stellar formation by regulating the flow of mass and angular momentum. Nevertheless, the physics governing the accretion and outflow in T Tauri stars is still poorly constrained. The use of high-resolution spectra offers a powerful probe for understanding the physics in these systems. However, due to the complexity of the environments, which include high-velocity gas flows, variable temperatures and densities, radiative transfer simulations are required to interpret the observed spectra. Our work uses the radiative transfer code TORUS to create synthetic spectra for atomic hydrogen in statistical equilibrium. Theory shows that outflows can originate from the disk, the star and the magnetosphere, but determining which of the possible mechanisms is the most dominant from the observations is difficult. We are developing models, which include magnetospheric accretion and outflows from the stellar surface. We present in this poster our first parameter study, which investigates the effects of mass-loss rate, temperature and velocity on synthetic hydrogen emission lines from stellar winds and magnetospheric accretion.

Activity and spin evolution of old main-sequence stars with asteroseismic ages

Katja Poppenhaeger (1); Rachel Booth (2); Silva Jarvinen (3)

(1) Leibniz Institute for Astrophysics Potsdam; (2) Queen's University Belfast; (3) Leibniz Institute for Astrophysics Potsdam

Stellar magnetic activity is not only an interesting physical phenomenon in its own right, but is also important for the evolution of exoplanet atmospheres and our statistical ability to detect planets around stars in the first place. The evolution of magnetic activity and rotation versus stellar age can be studied using open clusters for ages of up to a few hundred million years. However, this becomes much more difficult for older cool stars because there are no conveniently nearby old clusters to enable the age determination. An alternative pathway is given through asteroseismic age determinations for individual stars. We have performed a detailed study of coronal and chromospheric magnetic activity in cool stars with ages beyond a gigayear, using only stars with well-determined individual ages. We find that the activity of these stars continues to decline with a slope similar to that seen for younger clusters in the case of chromospheric activity, and with an even steeper slope for coronal activity. We do not see evidence of a sustained higher activity level, as one might expect from rotational studies finding a "coasting"-type behaviour. We argue that this puzzling discrepancy can be explained by the fact that stars with low chromospheric and coronal activity may not produce sufficient rotational modulation in their light curves due to the low contrast of spottedness on their hemispheres and may therefore be missing from rotation versus age studies.

Title: Optimizing TESS short cadence aperture for Asteroseismology of solar-like stars

Lucía González-Cuesta (1); Savita Mathur (2); Rafael A. García (3)

(1) IAC/Instituto de Astrofísica de Canarias; (2) ULL/Universidad de La Laguna; (3) IAC/Instituto de Astrofísica de Canarias; (4) ULL/Universidad de La Laguna; (5) Laboratoire AIM, CEA/DSM – CNRS; (6) Université Paris Diderot

Thanks to data collected by missions such as CoRoT and Kepler/K2, asteroseismology has demonstrated that it is a powerful tool to determine stellar parameters. With the launch of the NASA TESS (Transiting Exoplanet Survey Satellite) mission, a new opportunity arose to use this technique on a sample of more than 20,000 bright main-sequence and subgiant stars, one of the main objectives of

this mission being the search of Exoplanets through the transit method. The standard light curves provided by the TESS Science Processing Operations Center (SPOC) are optimized for exoplanet search and do not always allow us to detect oscillation modes in solar-like stars. Asteroseismic studies have shown that the ideal apertures are larger than the standard ones. These larger apertures increase the signal-to-noise ratio (SNR) of the oscillation modes of the stars, allowing us to better detect them.

In order to improve the detection rate of solar-like oscillations in the TESS data, we developed an automatic code to determine the optimal aperture to detect the oscillation modes for a large sample of solar-like stars, with a particular focus on planet host stars. The goal is to obtain an aperture for which the SNR of the modes is maximized while avoiding pixels that could contaminate the signal from the target star with flux from other nearby stars. For that, our selection of the pixels is based on differences of integrated flux between adjacent pixels, and we also select different thresholds for the integrated flux of each pixel, in order to create different aperture sizes.

Here we will present the methodology that we have developed and we will show some examples of how we improve the SNR and detection of the modes using our apertures compared to other apertures obtained within the community.

Shapes of stellar activity cycles

Teemu Willamo (1); Thomas Hackman (2); Jyri J. Lehtinen (3); Maarit J. Käpylä (4); Nigul Olspert (5); Mariangela Viviani (6); Jörn Warnecke (7)

(1) University of Helsinki; (2) University of Helsinki; (3) Max Planck Institute for Solar System Research; (4) Aalto University & Max Planck Institute for Solar System Research; (5) Max Planck Institute for Solar System Research; (6) Max Planck Institute for Solar System Research; (7) Max Planck Institute for Solar System Research

The sunspot cycle has an asymmetric shape, characterized by a fast rise from minimum to maximum and a slower decline from maximum to minimum. The shapes of magnetic cycles in other stars have not been studied extensively. We have analyzed stellar activity cycles identified from the Mount Wilson database of chromospheric Ca II H&K emission. We use the skewness of a cycle as a measure of its asymmetry, and compare it to other stellar parameters; chromospheric emission, rotation period, cycle period and effective temperature. No clear dependencies between these variables are found, but the solar shape (fast rise and slow decline) is common in other stars as well, although the Sun seems to have particularly asymmetric cycles. We have also analyzed magnetohydrodynamic simulated cycles, and compare them to the observations. There is a difference between global simulations covering the full longitudinal range, and simulations covering only a longitudinal wedge.

The Sun as a star as observed with ALMA

Sneha Pandit; Sven Wedemeyer

Rosseland Centre of Solar physics, Institute of Theoretical Astrophysics, University of Oslo

Since Sun is the closest star, we can study it in detail. Several observatories have given us insight on the different layers and structures on the sun and other stars. ALMA is a new set of eyes to look at the stars. So to re-evaluate the structure of stellar atmospheres and their activity, we use the ‘Sun as a star approach’. It is using solar observations to estimate properties or features of other stars and in the process understanding the solar-stellar structure a little better. Here, the full disk maps from ALMA are compared with SDO-AIA and HMI channels and, with H-alpha and Ca II maps to understand the correlation and also to estimate from what layer of the sun do these mm emissions

originate. The 2D histograms from comparison of ALMA with SDO and H-alpha maps show the expected trend of slight anti-correlation, because of the limb brightening or darkening effects. The centre to limb variation in temperature is observed for the maps. Also, for the comparison of the solar and stellar signals, the full disk map is converted into a corresponding stellar signal. The resulting stellar signals will then be used to construct suitable stellar activity indicators for stellar observations with ALMA.

Nonlinear Convergence of Solar-like Stars Chromospheres Using Millimeter, Submillimeter, and Infrared Observations

Victor De la Luz (1); Luis Zapata (2); Jacob White (3)

(1) IRyA/Universidad Nacional Autonoma de Mexico; (2) ENES-Morelia/Universidad Nacional Autonoma de Mexico; (3) Konkoly Observatory

In this work, we present a new methodology to fit the observed and synthetic spectrum of solar-like stars at millimeter, submillimeter, and infrared wavelengths through semiempirical models of the solar chromosphere. We use the Levenberg–Marquardt algorithm as a Nonlinear method, PakalMPI as the semiempirical model of the solar chromosphere, and recent observations from the Atacama Large Millimeter/submillimeter Array of solar-like stars. This method provides a new fast numerical tool to estimate the physical conditions in the atmosphere of solar-like stars.

The Role of Flare Morphology in Exoplanet Characterization

Guadalupe Tovar Mendoza; James R. A. Davenport; Suzanne L. Hawley

University of Washington, Seattle

Stellar variability has been shown to be a limiting factor for planet detection and characterization, particularly around active stars. Specifically, stellar flares can affect transit timing precision and can obscure our ability to accurately characterize exoplanets. We revisit one of the most active stars from the Kepler mission, the M4 star GJ1243, and use a sample of stellar flares from 11 months of 1-minute cadence light curves to study the empirical morphology of stellar flares. Here we present a new continuous flare template, that is an improvement on the Davenport et al. (2014) version, which uses the flare sample and a gaussian process regression to model stellar variability. The flare template is based on a continuous function with an analytic derivative, ideal for use in Hamiltonian Monte Carlo light curve modeling. By understanding the temporal evolution of flares on active M-dwarfs we can help improve exoplanet detection and characterization. We inject a planet transit into the light curve and explore how efficient our model is at recovering the transit in the presence of flares. By coupling stellar variability models to transit analyses we can improve retrieved exoplanet parameters and gain a clearer picture of the star plus planet system.

Albireo: a physical triple after all

Missael Hernandez Huerta; Klaus Peter Schroeder; Dennis Jack

Universidad de Guanajuato

Recently, the physical nature of the well-known triple system Albireo has come under debate. In particular, differences in GAIA parallaxes shed doubt on components A (a close binary dominated by a

K supergiant) and B (a hot main sequence star) forming a bound system and even sharing a common origin. To study these questions from a different perspective, we used the well-tested Eggleton stellar evolution code to compute evolutionary models, which match the three Albireo components (Aa, Ab and B) by their HRD positions on the slowest (most likely) segments of the respective evolution tracks, testing if a solution with a common age and distance would be available. The effective temperature of the K supergiant component Aa was redetermined using a spectroscopic analysis of high s/n, R=20,000 TIGRE-HEROS spectra. As distance we used 120 pc as the more reliable parallax of the single star Albireo B. We find that, indeed, all three Albireo components can be matched by stellar models with the same age of 89 Myrs, with masses of 5,2 (Aa), 3,0 (Ab), and 3,7 (B) solar masses. This result supports, at least, the idea of a common origin and physical nature of this triple system. Whether the wide A/B pair is still in a bound orbit, however, must be left to a dynamical study.

Magnetism in Betelgeuse: a high-resolution spectropolarimetric monitoring before and around its historic dimming

Stefan Georgiev (1); Agnès Lèbre (2); Renada Konstantinova-Antova (3); Philippe Mathias (4); Arturo López Ariste (5); Eric Josselin (6)

(1) Institute of Astronomy and NAO, Bulgarian Academy of Science; (2) Université de Montpellier, CNRS, LUPM; (3) Institute of Astronomy and NAO, Bulgarian Academy of Science; (4) IRAP, Université de Toulouse, CNRS, UPS, CNES; (5) IRAP, Université de Toulouse, CNRS, UPS, CNES; (6) Université de Montpellier, CNRS, LUPM

Results of high-resolution spectropolarimetric observations collected with the (Neo)Narval instrument at the Telescope Bernard Lyot (TBL) at Pic du Midi observatory, France, of the red supergiant star Betelgeuse (α Ori) obtained before and around its recent dimming episode are presented. The temporal evolution of the circularly polarized (Stokes V) signal within the profiles of spectral lines is shown, along with the behavior of the longitudinal magnetic field, B_l.

Kinematics, Multiplicity, and Angular Momentum Evolution of Ultracool Dwarfs through Forward-Modeling Analysis of Keck/NIRSPEC and SDSS/APOGEE High-Resolution Spectroscopy

Chih-Chun "Dino" Hsu (1); Adam J. Burgasser (2); Christopher A. Theissen (3); Jessica L. Birky (4); Christopher R. Gelino (5); Cullen H. Blake (6)

(1) University of California San Diego; (2) University of Washington; (3) Infrared Processing and Analysis Center; (4) University of Pennsylvania Department of Physics and Astronomy

It has been found that L dwarfs are kinematically more dispersed than late-M dwarfs, inconsistent with the current understanding of brown dwarf evolution. This discrepancy could be due to mass function evolution, incomplete understanding of brown dwarf evolution, or observational sampling bias. While there are more than 10,000 ultracool dwarfs (UCDs) now known, only a few hundred have 6D coordinates (positions and velocities) of sufficient precision to study their Galactic formation history and evolution, while very few T dwarfs have been measured in this manner. This UCD kinematic sample can be increased substantially through analysis of existing high-resolution spectroscopic archival data. Here we present analysis of 20 years of Keck/NIRSPEC archival data and SDSS/APOGEE DR16 spectra of 757 ultracool dwarfs obtained over 1961 epochs, based on a custom Markov Chain Monte Carlo forward-modeling algorithm. Combining these measurements with

Gaia DR2 and other ground-based astrometric data, we examine the 6D space coordinates of a volume-limited sample to derive kinematics ages as a function of spectral type. We find that the local T dwarf sample has a kinematic age of 4.1 $\pm$ 0.6 Gyr, consistent with late-M dwarfs as well as the predictions of brown dwarf population simulations, but both are significantly younger than nearby L dwarfs (5.6 $\pm$ 0.3 Gyr). We also evaluate Galactic orbits, young cluster membership, radial-velocity binaries, and vsini's across the late-M, L and T dwarf sequence.

Simultaneous mulit-wavelength observations with HELLRIDE

F. Tischer; A. Hanslmeier; M. Roth

IGAM/University of Graz, IGAM/University of Graz, Leibniz Institute for Solar Physics

We are working with the HEliospheric Large Regions Interferometric DEvice (HELLRIDE), a newly developed instrument installed on the Vacuum Tower Telescope (VTT) on Tenerife, operated by the Leibniz Institute for Solar Physics (KIS). This instrument is a 2-dimensional Fabry-Perot spectrometer capable of observing the solar photosphere and chromosphere simultaneously in up to 16 different wavelengths in a 4x4 filter mount and is intended to analyse flares and shockwaves in the solar atmosphere. By using spectral lines that are predominantly produced in different heights of the solar atmosphere, we analyze correlations between the Doppler velocities in these different heights. Authors: F. Tischer, A. Hanslmeier, M. Roth

Stellar activity indicators of M dwarfs from SPIRou

Pia Cortes-Zuleta; Isabelle Boisse; SPIRou team

Laboratoire d'Astrophysique de Marseille

SPIRou is a near-infrared (nIR) spectropolarimeter and a high-precision velocimeter mounted in the Canada-France-Hawaii telescope (CFHT) in Hawaii. Its scientific goals are two-folded: first, to search and characterize Earth-like planets around nearby low-mass stars, such as M dwarfs, using high-precision radial velocity (RV) measurements and second, to study the impact of magnetic fields in star and planet formation using spectro-polarimetry.

Currently, the main limitation to detect Earth-like planets using the RV technique is the presence of stellar activity. Stellar photometric effects introduce spurious RV signals that hamper the detection of exoplanets. Stellar activity indices can be derived from the analysis of the cross-correlation function (CCF) of the spectra in order to disentangle the stellar contribution from the planetary signal. For example, the bisector of the CCF shows a clear "C" shape in the presence of stellar spots, and the bisector inverse slope (BIS) is often anti-correlated with the spurious RV signal from the star. Moreover, some specific spectral lines, such as H_α, can be also used as indicators as they are sensitive to stellar activity.

We will present the ongoing work on stellar activity indices of a sub-sample of M dwarfs monitored with SPIRou. From their nIR spectra, we measured the bisector of the CCF, BIS and some specific spectral lines to characterize the stellar activity of this sub-sample.

Testing the accuracy and completeness of brown dwarf model atmospheres using high-dispersion spectroscopy

Megan E. Tannock (1); Stanimir Metchev (2); Callie Hood (3); Greg Mace (4); Jonathan Fortney (5); Caroline Morley (6)

(1) University of Western Ontario; (2) University of Western Ontario; (3) University of California Santa Cruz; (4) University of Texas at Austin; (5) University of California Santa Cruz; (6) University of Texas at Austin

Reliable determinations of the effective temperatures, radii, and masses of brown dwarfs and giant exoplanets are dependent on accurate modelling of their spectra. However, even the most up-to-date models do not completely reproduce observed spectral features in cool brown dwarfs, limiting our ability to constrain their basic properties. In this work we test where existing models and laboratory-based experimental line lists fall short for brown dwarf atmospheres by comparing them to high-dispersion (R$\sim$45,000), high-signal-to-noise near-infrared (1.45-2.50 micron) spectra of T dwarfs recently acquired by our team with the IGRINS instrument on Gemini South. We present the fundamental parameters of these objects and provide guidance to the community regarding the most reliable regions of the near-infrared spectrum for effective temperature, surface gravity, vsin(i), and radial velocity measurements.

A Refined Set of Main Sequence Stellar Rotation Periods from Kepler

Gibor Basri; Joanne Tan

UC Berkeley

The age of precision space-based light curves vastly increased the number of rotation periods known for main sequence stars. The primary reference for more than 30,000 rotation periods from the Kepler Prime mission has been McQuillan et al 2013 (McQ). They utilized an autocorrelation (AC) technique, whose results have largely been agreed with by many other analyses and methodologies. The primary uncertainty in the AC method occurs because stars sometimes exhibit two dips per rotation and sometimes only one. Basri & Nguyen (2017) found that this behavior is systematic with stellar rotation period and stellar temperature (more rapid rotators exhibit more single-dip behavior). We examine the issues caused by this for the AC method and in periodograms. Fewer than 10% of the McQ periods are double what they should be, mostly for periods greater than about 20 days. We present a refined AC method for determining rotation periods that also utilizes the distribution of light curve dip durations, and discuss the criteria by which we select the best period. We apply this method to the McQ sample, filtered by Gaia stellar parameters, and a similarly sized set of new (less variable) main sequence stars that McQ did not find periods for. A few thousand more periods are found in this extended sample; the rest really do not seem to exhibit rotational modulation.

TESS lightcurves as new chronometer through solar twins

Diego Lorenzo-Oliveira (1); Adriana Valio (2); Jorge Meléndez (3)

(1) Centro de Radioastronomia e Astrofísica Mackenzie, Universidade Presbiteriana Mackenzie; (2) Instituto de Astronomia, Geofísica e Ciências Atmosféricas, Universidade de São Paulo; (3) Centro de Radioastronomia e Astrofísica Mackenzie, Universidade Presbiteriana Mackenzie; (4) Instituto de Astronomia, Geofísica e Ciências Atmosféricas, Universidade de São Paulo; (5)

We investigate the impact of the chromospheric activity on NASA/TESS lightcurves of a selected sample of solar twins with well-determined ages. These stars also had their magnetic activity monitored by the high precision ESO/HARPS spectrograph. We estimate the photometric variability of lightcurves due to rotational modulations of stellar activity, and explore its correlations with chromospheric activity (Ca II lines), ages, and rotational periods. We show that the TESS photometric

amplitudes are strongly correlated with the mean chromospheric activity level of our sample stars, and also with rotational periods and stellar ages, being, thus, an essential diagnostic of stellar ages.

Periodicities, Rotation and Activity of Young Suns as seen by TESS

Eduardo Nunes Velloso; Leandro de Almeida; Ana Carolina Mattiuci; José Dias do Nascimento, Jr.

Universidade Federal do Rio Grande do Norte

The Transiting Exoplanet Survey Satellite (TESS) is providing us with an all-sky survey of more than 200,000 targets at short and continuous cadence. In contrast with Kepler's 4-year coverage of the same part of the sky, most TESS targets will not be observed for more than a few consecutive months. In fact, just like with the K2 mission, this presents a challenge to retrieve periodicities in the light curve at longer time scales, especially for older stars. In this work, seven G and K bright young dwarfs within 50 pc of the Sun and with recent TESS observations were selected based on having previous detailed literature descriptions. We find contamination issues in some cases and propose a novel light curve extraction technique. Together with traditional methods to detect signal periodicities (e.g. the generalized Lomb-Scargle periodogram and the autocorrelation function) we use a spot modeling framework to infer rotation patterns with solutions well constrained by spectroscopic observations. We find good fits for the most active stars, with rotation periods ranging between 7 and 11 days, indicating that TESS is a powerful observational tool to characterize rotation for young sun-like stars.

"Reading between the lines": How time- and velocity-resolved data can help us to map the tiniest scales in young forming stars

Aurora Sicilia-Aguilar (1); Justyn Campbell-White (2); Jerome Bouvier (3); Min Fang (4)

(1) University of Dundee; (2) University of Dundee; (3) University of Grenoble; (4) Caltech; (5)

Emission lines, together with variability, are one of the defining characteristics of young stars. Both carry an overwhelming amount of information about accretion and activity processes in the stellar magnetosphere and innermost disk. Using time-resolved, high-resolution spectroscopy covering several rotational and disk orbital periods, we can obtain a detailed view of the structure and variability of accretion columns and spots and information on the presence and launching points of stellar/disk winds in young stars. Time- and velocity-resolved emission (and absorption) line spectroscopy can also trace parts of the inner disk at scales that are not accessible by direct imaging or interferometry, while time-resolved photometry (ranging from short cadence like K2 or TESS, to long cadence ground-based observations) can help to complete the picture in terms of extinction and global structural changes in the innermost disk environment.

I will present the results of using time-resolved data to disentangle the innermost structure of young variable stars with spectral types ranging from M to B, including outbursting stars (e.g. EX Lup, ZCMa) and others suffering variable, quasiperiodic extinction (e.g RX J1604.3-2130). Understanding these processes and how they affect the observed spectra can also help us to identify (or rule out) the presence of newly-formed planets and stellar companions that may be perturbing the disk, distinguishing the spectral and photometric signatures of planets from those related to stellar variability and the variable structure of the inner disk.

Binary orbit and spot modelling of UX Arietis for the interpretation of radio flares

Christian Hummel (1); Anthony Beasley (2)

(1) European Southern Observatory; (2) National Radio Astronomy Observatory

We observed the RS CVn-type binary UX Ari with the CHARA infrared long-baseline interferometer and resolved the primary K2IV component in its orbit around the G4V secondary component. Combined with radial velocity measurements, the distance, masses, and luminosities of the stellar components could be obtained. Interferometric imaging with CHARA located a co-rotating spot on the primary during the month-long observation period. Using the orbit and light-curve modelling, we reconstruct the positions of the primary spot and the secondary component at several epochs at which radio observations with the VLBA detected flares. We aim to relate the astrometry of the quiescent radio emission, consisting of two distinct components, with the binary orientation, and discuss the evolution of a radio flare in the context of models based on magnetic loops anchored on the primary or interacting magnetospheres between the stars.

Rotational velocities and braking strength in main sequence stars.

Jefferson da Costa; João M. Machado; Francys Anthony; Hugo. R. Coelho; Matthieu Castro; José D. do Nascimento Jr.

Universidade Federal do Rio Grande do Norte

From a large sample composed of 10282 F, G, and K type main sequence stars, we investigated the rotational velocities distribution for those low mass stars. We developed theoretical distributions of the apparent rotational velocities, for different evolutionary stages, based on a statistical-phenomenological approach considering braking effect where observed distribution of rotational velocities for several spectral type stars can be understood in terms of braking strength. We analyzed the evolution of the rotational distribution, and we found stars follow a mass dependent angular momentum evolution law on the main sequence and some of them presenting an deviating behavior (faster rotators). For Main Sequence it is necessary to introduce an extra braking mechanism to ensure the angular momentum conservation law. We also re-derived the Skumanich Law with our theoretical approach. Finally we discuss the connection between the slow rotators along within the rotational distribution and the phenomenon that causes the rotational velocity distribution of these stars.

Contemporaneous Observations of Hα and Photometric Amplitude for M dwarfs

Aylin Garcia Soto (1); Elisabeth Newton (2); Stephanie Douglas (3); Aurora Y. Kesseli (4)

(1) Dartmouth College; (2) Dartmouth College; (3) Center for Astrophysics/Harvard & Smithsonian; (4) Boston University

Our proximity to the Sun has given us the unique opportunity to study the Sun's complex magnetic field and its manifestations in detail. While many M dwarfs are known to have strong magnetic fields and high levels of magnetic activity, we are still unsure about the properties of their starspots and the origin of their magnetic dynamos. Both starspots and Hα emission are related to the surface magnetic field activity, the former which can be measured from the photometric amplitude variability.

How photometric variability and magnetic activity are related therefore provides a means to examine starspots and magnetic heating on M dwarfs. We present time-series optical photometry from the Transiting Exoplanet Survey Satellite (TESS) and contemporaneous optical spectra obtained using the Ohio State Multi-Object Spectrograph (OSMOS) on the MDM 2.4m telescope in Arizona. After removing stellar flares, we measure photometric amplitudes, and confirm the rotation periods. We also calculate the equivalent width of Hα. Here, we present our first results investigating the relationship between these properties.

Tidal synchronization and rotation of late-type binaries

Jefferson da Costa (1); José D. do Nascimento Jr. (2); Ana C. Mattiuci (3); Paul G. Beck (4); Francys Anthony (5); Leandro de Almeida (6); Matthieu Castro (7)

(1) Universidade Federal do Rio Grande do Norte; (2) Universidade Federal do Rio Grande do Norte, Harvard-Smithsonian Center for Astrophysics; (3) Universidade Federal do Rio Grande do Norte; (4) Instituto de Astrofísica de Canarias, Institute of Physics Universität Graz; (5) Universidade Federal do Rio Grande do Norte; (6) Universidade Federal do Rio Grande do Norte; (7) Universidade Federal do Rio Grande do Norte

Binary systems with an evolved stellar component, distributed over all phases of stellar evolution, give us important constraint about the role played by convection on the characteristic time for tidal synchronization and circularization. The primary goal of this study is to compile a comprehensive compilation of observational parameters for binaries with late-type primary as a tested for the tidal theory of the equilibrium tide. In this context, we aim to analyze the rotational behavior, the evolutionary status and to compute the normally neglected influence of the convective envelope on the tidal forces and orbital evolution. A sample of 385 spectroscopic binary systems with published orbital solutions to better constrain the evolutionary stage of the evolved primary component with spectral type F, G and K has been selected for an in-depth analysis. We determine the depth of the convective envelope from stellar models for an improved position in the Hertzsprung-Russell diagram, using GAIA parallaxes. From these revised models, we calculate the theoretical circularization and synchronization timescale and compare it with the orbits eccentricities and primary component rotation rate. This work provide a unprecedented compiled sample of observational parameters for spectroscopic binary systems with late-type component. We refine the evolutionary status of this sample and we present the determined orbital solutions within fundamental parameters. Our results confirm the success of the Zahn's theory under the light of new data and new stellar evolutionary models and we demonstrate how the tidal efficiency is affected by variations of the convective *f* deepening factor. Our results show that the Zahn's theory applied for misclassified no-evolved star sample produce large errors on the circularization time scale. We present also a consistent analysis of the synchronization and rotation of binaries with late-type component. The relation between stellar rotation and orbital period is presented as a function of stellar radius. First results points toward the mass in the convective envelope as a governing parameter which has mainly been neglected in previous observational studies.

Slingshot prominences as a mechanism for mass and angular momentum loss in young M-dwarfs

Rose F.P. Waugh; Moira M. Jardine

University of St Andrews

Slingshot prominences are cool condensations of plasma that are enforced in co-rotation with rapidly rotating stars. They are typically 10-100 times the mass of solar prominences and form around the co-rotation radius of a star (rather than a few km above the solar surface). They have been most well observed on the young-Sun AB Doradus, although they have been observed in a range of systems, including on M-dwarfs. Their prevalence across the stellar spectrum suggests that these features could be common within low mass stars. The prominence material is known to be supported in co-rotation by the stellar magnetic field, thus the locations of these features allow for inferring of the field structure at these locations. Their ejection from the star could also be a mass or angular momentum loss mechanism for the star in its youth, when the prominences are large and held multiple stellar radii above the stellar surface. We investigate the formation of these prominences in a sample of M-dwarfs. Using Zeeman Doppler Imaging maps of our stellar sample, the magnetic field structure within the corona can be constructed, assuming a potential field. The prominence formation sites for these stars on these particular years was then modelled by searching for the stable equilibrium locations within the constructed field topologies. All maps used result in predicted prominence formation sites, though in many cases we predict that these prominences would not have been visible from Earth due to the geometry of the system. Despite our prediction that most of these stars would not have hosted any prominences visible to us, we show that these features should not be ignored. We compare the mass and angular momentum loss rates of the prominences to the stellar isothermal wind, showing that in some cases the prominence mass lass rates can be greater than the wind itself.

Simulations of solar-like stars at varying rotation rates: where do we stand in comparison to observations?

M. Viviani (1); J. Warnecke (2); M. J. Käpylä (3); P. J. Käpylä (4); N. Olspert (5); E. M. Cole-Kodikara (6); J. Lehtinen (7); A. Brandenburg (8)

(1) Max Planck Institute for Solar System Research, Göttingen, Germany; (2) Max Planck Institute for Solar System Research, Göttingen, Germany; (3) Astroinformatics group, Department of Computer Science, Aalto, Finland and Max Planck Institute for Solar System Research, Göttingen, Germany; (4) Institut für Astrophysik, Georg-August-Universität, Göttingen, Germany and Astroinformatics group, Department of Computer Science, Aalto, Finland; (5) Max Planck Institute for Solar System Research, Göttingen, Germany and Astroinformatics group, Department of Computer Science, Aalto, Finland; (6) Leibniz Institute for Astrophysics, Potsdam, Germany; (7) Max Planck Institute for Solar System Research, Göttingen, Germany and Astroinformatics group, Department of Computer Science, Aalto, Finland; (8) NORDITA, Stockholm, Sweden and Department of Astronomy, Stockholm University, Stockholm, Sweden and JILA and Department of Astrophysical and Planetary Sciences, University of Colorado, Boulder, USA

Rotation is one key parameter characterising stellar activity and dynamos. Studies of long-term photometric datasets derived a limiting activity measure above which stars show active longitudes (e.g., [1]). These active longitudes are thought to be the result of non-axisymmetric dynamos operating in stellar convection zones. Also the magnetic cycle length changes as a function of rotation. The new datasets also change the nature of the so-called “activity branches” ([2]). While previous studies identified three populations of stars (Inactive, Active and Superactive), longer datasets seem to confirm the existence of the Inactive branch, but question the existence of Active population (e.g., [3]). Solar-like solutions in global 3D magneto-convection models are routinely obtained and the simulations can be integrated long enough so that also the long-term behaviour of the solar cycle can be captured (e.g., [4]). By varying the rotation rate, also stellar cycles can be studied numerically. We performed such a study in [5], and compared our results with the current simulations and observations. Fast rotating simulations show non-axisymmetric large-scale magnetic fields, while

slow rotating ones have axisymmetric magnetic fields. Our transition, though, occurs earlier than in observations. Although the rotation rates covered in our study should correspond to Inactive and Active/Superactive stars, numerical models recover only the Superactive population, while the Inactive branch cannot be reproduced.

References [1] Lehtinen, J., Jetsu L., Hackman T., Kajatkari P. & Henry, G. W., A. 2016, A&A, 588, A38. [2] Saar, S. H. & Brandenburg, A., A. 1999, ApJ, 295-310, 524. [3] Olspert, N., Lehtinen, J. J., Käpylä, M. J., Pelt, J. & Grigorievskiy, A. 2018, A&A, 619, A6. [4] Käpylä, M. J., Käpylä, P. J., Olspert, N., Brandenburg, A., Warnecke, J., Karak, B. B. & Pelt, J., A. 2016, A&A, 589, A56. [5] Viviani, M., Warnecke, J., Käpylä, M. J., Käpylä, P. J., Olspert. N., Cole-Kodikara, E. M., Lehtinen, J. & Brandenburg, A., A. 2018, A&A 616, A160.

How to Date a Cluster: Updated Ages of Nearby Stellar Clusters

Mackenna L. Wood (1); Andrew Mann (2); Pa Chia Thao (3); Aaron Rizzuto (4)

(1) University of North Carolina at Chapel Hill; (2) University of North Carolina at Chapel Hill; (3) University of North Carolina at Chapel Hill; (4) University of Texas at Austin

Accurate and precise ages of stars are essential for testing models of stellar and planetary evolution. Young clusters, moving groups, and star-forming regions are particularly useful here, as their member stars likely formed from the same molecular cloud and therefore have similar or identical ages. Gaia has identified new associations and more members for many known groups, facilitating new studies and increasing their utility for stellar astrophysics, provided their ages can be accurately determined. We introduce a survey of these newly found and poorly studied young groups to determine their ages from Lithium abundances of their low-mass members. We focus on the Lithium depletion method, because it is more robust to changes in model parameters as compared to other methods. It is also well suited to assigning ages to young clusters, as it works well on stars between 20 and 200 Myr, covering the “golden age” of planetary evolution, after planets have formed but while they are still undergoing critical changes, like migration and atmospheric photoevaporation. We present early results from this survey, including clusters targeted, member selection and prioritization, and preliminary findings from moderate-resolution spectra taken with the Goodman spectrograph on SOAR.

The Lowell Observatory Solar Telescope

Joe Llama (1); Debra Fischer (2); Michael Collins (3); David Sawyer (4); John-Michael Brewer (5); Andrew Szymkowiak (6); Ryan Blackman (7); Ryan Petersburg (8)

(1) Lowell Observatory; (2) Yale; (3) Lowell Observatory; (4) Lowell Observatory; (5) San Francisco State University; (6) Yale; (7) Yale; (8) Yale.

One main hurdle remains in detecting a terrestrial exoplanet orbiting in the habitable zone of a Sun-like star. The star itself can induce radial velocity jitter of several m/s, completely drowning the minuscule signal from an orbiting planet. Understanding this jitter has proved extremely challenging since the majority of stellar surfaces are unresolved.

The EXtreme PREcision Spectrograph (EXPRES) has recently been commissioned on the Lowell Observatory Discovery Telescope. EXPRES is capable of reaching the precision necessary to detect Earth-like exoplanets orbiting nearby bright stars. I will present The Lowell Observatory Solar Telescope (LOST). LOST features two telescopes, the first of which feeds sunlight into EXPRES during the day to provide high-cadence observations of the Sun in an analogous way to stars at night. LOST also has a second telescope that will provide high-resolution images of the solar-disk

in Calcium-K (393 nm) to accompany every spectrum. I will present an overview of the instrument, science goals, and the results of the first month of operation.

Regular and oscillatory motion of Coronal bright points

Tamar Tsinamdzgvrishvili (1); Bidzina Shergelashvili (2); Bidzina Chargeishvili (3); Irakli Mghebrishvili (4); Tengiz Mdzinarishvili (5); Darejan Japaridze (6)

(1) Evgeni Kharadze Georgian National Astrophysical Observatory; (2) Evgeni Kharadze Georgian National Astrophysical Observatory & Space Research Institute, Graz, Austria & KU Leuven campus Kortrijk, Kortrijk, Belgium; (3) Evgeni Kharadze Georgian National Astrophysical Observatory; (4) Evgeni Kharadze Georgian National Astrophysical Observatory; (5) Evgeni Kharadze Georgian National Astrophysical Observatory; (6) Evgeni Kharadze Georgian National Astrophysical Observatory

Long-term automatic tracing of Coronal bright points made it possible to study their proper motion using the SDO/AIA channel AIA 193 data. For processing the series of chosen fits files, we took 95 visually long-lived bright points where possible homogeneously distributed along the latitude. Specially developed code automatically detects heliographic coordinates of the centroid of the chosen Coronal bright points in a series of fits files. The final results of all studied Coronal bright points show apparent oscillatory character in their proper motion. Oscillation periods range from 5 to 60 hours with an average of 20 hours. Some trends of latitudinal dependence of oscillation characteristics are revealed. There is supposed that these oscillations are the result of propagation of helical waves along the magnetic loops, constructing Coronal bright points. Using the linear trends of latitudinal and longitudinal components of the movement of the Coronal bright points, we obtained their rotational rates and the meridional migration speeds. The results of the rotational rates are confirming the differential character of latitudinal dependence.

Mapping the Progression of Star Formation in the Sco-Cen Association

Ronan M. P. Kerr; Aaron C. Rizzuto; Adam L. Kraus

University of Texas at Austin

The Sco-Cen OB association is the nearest site of recent large-scale star formation to the sun (100-150pc) and contains roughly 10000 members. Due to its diversity, large size, complex star formation history, and relative accessibility due to distance, Sco-Cen provides an ideal environment in which to study the output of star formation prior to dissipation into the galactic disk. With the most recent data from Gaia DR2, it is now possible to study the star-formation history and substructure of Sco-Cen in detail. I have used Gaia photometry and parallaxes to identify young stars using an isochrone-generated model stellar population. Analyzing all high-quality Gaia stars with parallax > 3 mas, I have identified about 18000 stars on the pre-main sequence with photometric ages of less than 30 Myr, including members of previously unidentified associations. Gaia proper motion measurements reveal that nearly 5700 of these pre-main sequence stars are members of Sco-Cen. My results reveal the internal structure of the association, and describe the formation, motion, and subsequent dispersal of these young stars throughout the region's history.

Finding members in star-forming regions and open clusters: A machine learning approach.

J. Olivares (1); H. Bouy (2); L.M. Sarro (3); N. Miret-Roig (4); P.A.B. Galli (5); E. Moraux (6); A. Berihuete (7)

(1) Université de Bordeaux; (2) Université de Bordeaux; (3) National University of Distance Education; (4) Université de Bordeaux; (5) Université de Bordeaux; (6) Université Grenoble Alpes; (7) University of Cádiz

In the era of big surveys the data processing pipelines have to keep peace with the tsunami of data. We will present a machine learning algorithm dedicated to find members of star-forming regions and open clusters in the solar vicinity. This algorithm is able to disentangle group members within data sets of millions of sources by means of the astrometric and photometric observables, while correctly propagating their uncertainties. Our new candidate members are typically low-mass stars and brown dwarfs that algorithms from the literature are unable to detect.

Magnetic field and chromospheric activity of the late-F star HD75332

Emma L. Brown (1); Stephen C. Marsden (2); Matthew W. Mengel (3); Sandra V. Jeffers (4); Isaac Millburn (5); Marco Mittag (6); The BCool Collaboration (7)

(1) University of Southern Queensland, Centre for Astrophysics; (2) University of Southern Queensland, Centre for Astrophysics; (3) University of Southern Queensland, Centre for Astrophysics; (4) Institut für Astrophysik, Georg-August-Universität; (5) University of Southern Queensland, Centre for Astrophysics; (6) Hamburger Sternwarte, Universität Hamburg

Studying cool star magnetic activity gives insight into the stellar dynamo and its relationship with stellar properties, as well as allowing us to place the Sun's magnetism in the context of the stars. Only two stars are currently known to have magnetic cycles similar to the Sun's, where the large-scale magnetic field reverses in phase with chromospheric activity cycles. One of these is τ Boötis (F8V) which has a $\sim$240d magnetic cycle, though it is not yet clear whether the rapid cycle is related to the star's thin convection zone or if the dynamo is accelerated by interactions between τ Boötis and its orbiting Hot Jupiter (HJ). To shed light on this, we studied the magnetic activity of HD75332 (F7V) which is a twin to τ Boötis and does not appear to host a HJ. We characterized its long term chromospheric activity variability over 53yrs and used Zeeman Doppler Imaging to reconstruct the large-scale surface magnetic field for 12 epochs between 2007 and 2019. Our results suggest that HD75332 has a rapid $\sim$1.06yr solar-like magnetic cycle where the magnetic field evolves in phase with chromospheric activity and large-scale polarity reversals occur at chromospheric activity cycle maxima. This is similar to the rapid magnetic cycle observed for τ Boötis, suggesting that rapid magnetic cycles may be intrinsic to late-F types and related to their shallow convection zones.

Multi-wavelength observations of stellar flares on an active M dwarf AD Leonis with Seimei/OISTER

K. Namekata(1); H. Maehara(2), R. Sasaki(3,4), H. Kawai(3), Y. Notsu(5,6), A. F. Kowalski(5,6), W. Iwakiri(3,4), Y. Tsuboi(3), K. Murata(7), M. Niwano(7), K. Shiraishi(7), R. Adachi(7), K. Iida(7), M. Oeda(7), M. Tozuka(8), N. Katoh(8), H. Onozato(8), S. Honda(8), K. Isogai(1), M. Kimura(1), N. Kojiguchi(1), Y. Wakamatsu(1), Y. Tampo(1), S. Okamoto(1), D. Nogami(1), K. Shibata(1)

(1) Kyoto Univ., (2) NAOJ, (3) Chuo Univ., (4) RIKEN, (5) LASP, Univ. of Colorado Boulder, (6) NSO, (7) Tokyo Institute of Tech., (8) Univ. of Hyogo

Stellar flares are energetic explosions on stellar surfaces, and there is an increasing interest on their properties from the perspective of the exoplanet habitability around cool dwarfs. In this presentation, we report multi-wavelength monitoring observations of an M-dwarf flare star AD Leonis, mainly with Seimei Telescope, OISTER (Optical and Infrared Synergetic Telescopes for Education and Research) program and NICER X-ray instrument onboard ISS. Twelve flares were detected in total which include ten Hα, four X-ray, and four optical-continuum flares; one of them is a superflare with the total energy of ~2.0×10^{33} erg. We found that (1) during the superflare, the full width at 1/8 maximum of the Ha emission line dramatically increases to 14 Å from 8 Å in the low resolution spectra (R~2000) accompanied with the large white-light flares, (2) some weak Hα/X-ray flares are not accompanied with white-light emissions, and (3) the non-flaring emissions show clear rotational modulations in X-ray and Hα intensity in the same phase. To understand these observational features, one-dimensional flare simulations are performed by using the RADYN code. As a result of simulations, we found Ha spectrum produced with the simulation with hard- and high-energy non-thermal electron beam is consistent with that of the initial phase spectrum of the superflares, while that with more soft- and/or weak-energy beam is consistent with that in decay phases. This suggests the changes in the energy fluxes injected to the lower atmosphere. Also, we found that the relation between the optical continuum and Hα intensity is found to be non-linear, which can be one cause of the non-white-light flares. The flare energy budget is indicated to have a diversity from the observations and models, and more observations of stellar flares are necessary for the understandings of the universality and diversity of stellar flares.

Statistical analyses of superflares on Sun-like stars using all Kepler 4-year data

Soshi Okamoto(1) (1); Hiroyuki Maehara(2) (2); Yuta Notsu(3,4) (3); Kai Ikuta(1) (4); Kosuke Namekata(1) (5); Shota Notsu(5) (6); Satoshi Honda(6) (7); Daisaku Nogami(1) (8); Kazunari Shibata(1) (9)

(1) (1)Kyoto University; (2) (2)NAO; (3) (3)LASP, University of Colorado Boulder; (4) (4)NSO; (5) (5)RIKEN; (6) (6)University of Hyogo

Solar flares are energetic explosions in the solar atmosphere, and superflares are the flares having the energy $10 - 10^6$ times larger than that of the largest solar flare. It had been thought that superflares cannot occur on slowly-rotating solar-type (G-type main-sequence) stars like the Sun. Recently, many superflares on solar-type stars were found in the initial 500 days data obtained by the Kepler spacecraft (Maehara et al. 2012; Shibayama et al. 2013). Notsu et al. 2019 conducted precise measurements of the stellar parameters and binarity check on the basis of spectroscopic observations and the Gaia-DR2 data. As a result, the number of Sun-like (slowly-rotating solar-type) superflare stars significantly decreased. In this study, we searched for superflares using all the Kepler data covering ~1500 days, adding the targets newly identified as solar-type stars. These increased total volume of data (the number of stars × observation period) by about 12 times. As a result, the number of superflares on Sun-like stars greatly increased from 3 to 29, which enabled better statistical studies of superflares on Sun-like stars. We found: (i) Sun-like stars can cause superflares up to about $5 \times 10^{34} erg$ once every several thousand years, (ii) the upper limit of the flare energy decreases as the rotation period (stellar age) increases in solar-type stars, and (iii) the frequency of superflares decreases as the stellar age increases. The point (i) strongly supports the possibility of superflares on the Sun. The points (ii) and (iii) are physically consistent with the result that the total area of starspots on the stellar surface decrease as the rotation period increases (Maehara et al. 2017). These results correspond with Notsu et al. (2019).

Star-disk interactions of the T Tauri star V2129 Oph: confronting optical and infrared spectroscopy

A. Sousa (1); J. Bouvier (2); S. Alencar (3); E. Alecian (4); C. Dougados (5); Donati J. F. (6)

(1) Université Grenoble Alpes; (2) Université Grenoble Alpes; (3) Universidade Federal de Minas Gerais; (4) Université Grenoble Alpes; (5) Université Grenoble Alpes; (6) Université de Toulouse

In this work, we aim to understand the dynamics of the magnetic star-disk interaction process in young stellar objects, as part of the SPIDI project. We present the case of the young star, V2129 Oph, which is a well-known T Tauri star with spectral type K5, located in the ρ Oph star formation region. We perform the time series analysis of this star using data from high-resolution spectroscopies in the optical wavelength, from ESPaDOnS/CFHT and HARPS/ESO, and in the infrared wavelength, from SPIRou/CFHT. This dataset allowed analyzing a possible accretion variation over the time scale of a decade in concern to a previous observational campaign of this system. We analyzed the variability of different circumstellar lines, such as Hα and Hβ, in the optical and HeI (10830 $\mathrm{\AA}$) and Paβ, in the infrared. We measure the periodicity and the correlation matrices of these lines. Through that, in the case of V2129 Oph, we show that the optical and the infrared lines profile variations are consistent with a magnetospheric accretion scenery with a period of $\sim 6\,\mathrm{days}$. Additionally, the optical lines present strong indications of a structure beyond the co-rotation radius, that vary periodically. We are investigating the possibility of a disk wind component dominate the variability of this star.

Injecting Y dwarfs into Gaia DR2 using HST: a new method to measure parallaxes and proper motions for our coolest neighbours

Clémence Fontanive (1); Luigi R. Bedin (2)

(1) CSH/University of Bern; (2) INAF/Osservatorio Astronomico di Padova

The new Y spectral sequence, classifying objects with effective temperatures <500 K, is filling a crucial gap in mass and temperature between brown dwarfs and Jupiter, offering ideal proxies to study planet-like atmospheres. However, only ~25 Y dwarfs have been confirmed so far, and their physical and atmospheric properties are still poorly understood. The lack of reliable distance estimates to calibrate these systems is a key factor in our incomplete knowledge of these pivotal giant planet analogues. Indeed, cool substellar objects are generally too red and too faint to be detected by surveys like Gaia, and current distance determinations for Y dwarfs remain highly undependable due to the difficulties associated with observations of such intrinsically faint objects. We present a new method devised to measure highly-precise parallaxes and proper motions for ultracool brown dwarfs. By exploiting the Gaia DR2 astrometric solutions for bright stars in HST field of views, the exquisite astrometric precision of HST can be translated into an absolute reference frame with an equally exquisite astrometric accuracy. In particular, the combination of HST and Gaia DR2 in this way can enable the derivation of astrometric parameters with Gaia-level precisions for sources like Y dwarfs, that are certainly too dim for Gaia. This new approach can achieve uncertainties of less than $1-2$ mas on parallaxes and at the ~0.3-mas level on proper motions, with a minimal three epochs of HST observations acquired over half a decade. New, accurate distances for Y dwarfs will allow for robust assessments of inherent properties, providing critical information to constrain theoretical models at the coldest temperatures. Precise kinematics will also provide valuable insights to trace the origin of Y dwarfs in the galaxy, enabling new constraints on their ages and natal environments.

Variability of veiling in DK Tau's spectra

Marie Nelissen; Pauline McGinnis; Devaraj Rangaswamy; Tom Ray

Dublin Institute for Advanced Studies

Classical T Tauri stars (cTTs) are actively accreting from their circumstellar disk. Because this accretion is very variable, we can study the variability to gain insight into the physical processes taking place in the environment around cTTs. In this work, we focus on the variability of veiling (defined as the ratio between the flux of the accretion shock and the photospheric flux), as a direct evidence of accretion, for a specific cTTs. Additionally, veiling must be taken into consideration when measuring other aspects of spectroscopy in actively accreting young stars (e.g. in trying to measure their magnetic field using the Zeeman effect), as it will strongly affect the shapes of the absorption lines in the spectra. DK Tau, a cTTs, was observed 9 times over 16 nights in 2010 with the optical spectropolarimeter ESPaDOnS mounted at the CFHT. We present the first results of our analysis of the variability of veiling in its spectra. To determine its veiling, we fitted a rotationally broadened and artificially veiled weak-lined T Tauri star (wTTs) spectrum on DK Tau's observed spectra. This wTTs can be seen as the purely photospheric version of our star because it experiences no accretion. We selected TaP45, a star which has the same spectral type as DK Tau, as our wTTs template, then estimated the veiling across our spectra and fitted either a polynomial function of second order or a constant value through our points (stretching across a wavelength range from 550 to 900nm). We find that DK Tau's veiling varies from night to night, and across each spectrum, with values ranging from 0 to 1.2. Furthermore, our results show that the shape of the veiling over the wavelength range (and not just the average veiling value) fluctuates over time. In conclusion, we find that accretion is particularly variable (over a timescale of 16 days) for DK Tau, showing that it is a very active cTTs. In the future, we plan to use these results to remove the effect of veiling from its spectra in order to properly study the Zeeman effect in this star's photospheric lines.

Wide Binary Star Systems and Ghost Star Clusters in the Kepler Field

Kenneth Janes

Boston University

Using a simple procedure to identify stellar systems in the GAIA DR-2 data that makes simultaneous use of all five dimensions of the available Gaia data, I searched an eight-degree radius area centered on the original Kepler spacecraft field. In addition to recovering the four well-known rich open clusters in the Kepler field, I identified large numbers of wide binary pairs (common proper motion stars) and several loose groups of mostly young stars, mostly on the southeast, low galactic latitude, portion of the field, and I found two previously unknown sparse, but clearly identifiable old star clusters. The existence of these two clusters is consistent with other recent analyses showing that there are two versions of what might be called "ghost" clusters - those that are real but are not obvious on most optical images of a field, and others that are listed in many cluster catalogs, but which are not detectable in the Gaia dataset. Finally, the overwhelming majority of the systems identified by my program consist of pairs and a few triples of stars with separations of 0.25 pc or less (a little over 50000 AU). Nearly all of these are highly likely to be physical systems, i.e., wide binary star pairs.

SEEJ: Smallsat Explorer of the Exospheres of Hot Jupiters

Scott J. Wolk for the SEEJ team

(1) Center for Astrophysics| Harvard & Smithsonian; (2) MSFC; (3) Moog Aerospace

The first detected exoplanets found were "hot Jupiters"; these are large Jupiter-like planets in close orbits with their host star. The stars in these so-called "hot Jupiter systems" can have significant X-ray emission and the X-ray flux likely changes the evolution of the overall star-planetary system in at least two ways: (1) the intense high energy flux alters the structure of the upper atmosphere of the planet - in some cases leading to significant mass loss; (2) the angular momentum and magnetic field of the planet induces even more activity on the star, enhancing its X-rays, which are then subsequently absorbed by the planet. If the alignment of the systems is appropriate, the planet will transit the host star. The resulting drop in flux from the star allows us to measure the distribution of the low-density planetary atmosphere. We describe a Pioneer mission, The SmallSat Exosphere Explorer of hot Jupiters (SEEJ; pronounced "siege"). SEEJ will monitor the X-ray emission of nearby X-ray bright stars with transiting hot Jupiters in order to measure the lowest density portion of exoplanet atmospheres and the coronae of the exoplanet hosts. SEEJ will use revolutionary Miniature X-ray Optics (MiXO) and CMOS X-ray detectors to obtain sufficient collecting area and high sensitivity in a low mass, small volume and low-cost package. SEEJ will observe scores of transits occurring on select systems to make detailed measurements of the transit depth and shape which can be compared to out-of-transit behavior of the target system. The depth and duration of the flux change will allow us to characterize the exospheres of multiple hot Jupiters in a single year. In addition, the long baselines (covering multiple stellar rotation periods) from the transit data will allow us to characterize the temperature, flux and flare rates of the exoplanet hosts at an unprecedented level. This, in turn, will provide valuable constraints for models of atmospheric loss. In this contribution we outline the science of SEEJ and focus on the enabling technologies Miniature X-ray Optics and CMOS X-ray detectors.

Stellar XUV radiation and the evolution of exoplanets

Simon Joyce; John Pye; Jonathan Nichols for the Exoplanets-A consortium

University of Leicester

The high-energy X-ray and UV radiation of late-type stars is one of the most important influences on planetary conditions. This radiation can heat a planet's atmosphere, affecting its structure, and also drive chemical reactions which produce biologically important molecules. In more extreme cases, stellar XUV radiation can evaporate atmospheres and oceans, and may be responsible for the "radius valley" observed in the close-in super-Earth population. An understanding of stellar magnetic dynamos, atmospheres and evolution has a direct link to the search for habitable worlds. We present work on behalf of the Exoplanets-A consortium which is creating a comprehensive catalogue of host star optical, IR and XUV observations, as well as extreme-UV modelling, in order to better understand stellar XUV radiation and explore the full range of effects host stars have on their planets.

The chromospheric activity of M Dwarfs from visible and near-infrared CARMENES spectra: analysis of flux-flux relationships

Fernando Labarga (1); David Montes (2); J.A. Caballero (3); Quirrenbach (4); P. J. Amado (5); I. Ribas, A. Reiners (6); W. Seifert (7); S. Jeffers and the CARMENES Consortium (8)

(1) Universidad Complutense de Madrid; (2) Max-Planck-Institut für Astronomie; (3) Instituto de Astrofísica de Andalucía; (4) Landessternwarte Königstuhl; (5) Institut de Ciències de l'Espai; (6) Institut für Astrophysik Göttingen; (7) Instituto de Astrofísica de Canarias; (8) Thüringer Landessternwarte Tautenburg; (9) Hamburger Sternwarte; (10) Centro de Astrobiología; (11) Calar Alto Observatory http://carmenes.caha.es/

CARMENES (http://carmenes.caha.es/) is a ultra-stable, double- channel spectrograph at the Spanish-German 3.5 m Calar Alto telescope for radial-velocity surveys of M dwarfs with the aim of detecting Earth-mass planets orbiting in the habitable zones of their host stars. The CARMENES survey, which began in January 2016 and is active nowadays, aims to observe approximately 300 M-type dwarf stars, spread over the complete M spectral range. The main objective of this work within CARMENES is the extraction of all available information on the chromospheric activity and its variability (rotational modulation, flares, etc.) using for that all the chromospheric indicators included in the spectral range of the spectrograph, ranging from visible (VIS) that include the Na I D1, D2 HeI D3, and H_α lines to near-infrared (NIR) that include the Ca II IRT, HeI 10830 Å, Paschen γ and Pβ lines. It is intended to carry out this task applying the spectral subtraction technique, and to this end it has been used a Python code (iSTARMOD) based on a previous FORTRAN one, formerly used by the research group. The detailed analysis of these activity indicators is important from one side in order to confirm or discard all the possible planets around these stars and by the other studying its dependency with other stellar parameters as rotation, age and depth of the convective zone. Studies of flux-flux relationships of lines formed at different chromosphere layers are the subject of this communication, aimed to a better understanding of the magnetic activity of M-type dwarf stars. Likewise, calibrations of the conversion function from EW to Fline/FBol as in Reiners/Basri [2008] extended to additional lines in Visible and NIR will be provided.

Using PLATYPOS to estimate the atmospheric mass loss of V1298 Tau's four young planets

Laura Ketzer; Katja Poppenhaeger

Leibniz Institute for Astrophysics Potsdam (AIP) & University of Potsdam

Kepler observations revealed two striking features in the distribution of explanet radii. One is a dearth of short period sub-Neptune-sized planets, and the second is a relatively clean gap around 2 $R_\oplus$. Atmospheric escape of planetary H/He envelopes driven by the high-energy X-ray and UV irradiation from the host star can explain the presence of this so-called photoevaporation desert and valley. Planets below the gap belong to the class of smaller, likely rocky super-Earths, while planets above the gap retain gaseous (H/He) envelopes greater than a few percent of the total planetary mass.

We developed PLATYPOS (PLAneTarY PhOtoevaporation Simulator), an open-source tool to model the (energy-limited) atmospheric escape of planetary systems over several Gigayears. We take into account the observed spread in X-ray luminosities of stars with similar spectral types at young ages by allowing the host star to spin down at a wide range of ages. This exposes a planet to varying levels of X-ray irradiation over time, which translates to a significant change in the mass loss rates. Our focus lies on exploring the effect of the host star's high energy evolution on the planetary mass and radius evolution, which is neglected in many previous photoevaporation studies.

We investigate V1298 Tau, a young ($\sim$ 20 Myr), X-ray bright ($\log L_X$ [erg/s] $= 30.1$) host star which is orbited by four Neptune- to Jupiter-sized planets with periods between 8 and 60 days. We calculate the future photoevaporative mass loss rates for a low, intermediate and high activity stellar evolutionary track. Our findings show that in certain planetary mass and orbital distance regimes, the stellar high-energy evolution evolution determines if a planet is stripped completely or can retain some fraction of its initial gaseous envelope. The next step is to evolve a synthetic population of exoplanets using an ensemble of different high-energy evolution tracks, and to investigate if host star evolution is a factor in explaing the fuzziness of the boarders of the photoevaporation desert and valley.

Ruprecht 147 - The oldest nearby open cluster in the light of gyrochonology

David Gruner: Sydney Barnes

Leibniz-Institute for Astrophysics Potsdam (AIP)

We present rotation periods for cool stars in the oldest (2.5 Gyr) nearby (within 500 pc) open cluster Ruprecht 147. The cluster was observed by Kepler during the 7th campaign in its K2 mission. We used cluster membership information from Gaia DR2 to compile a list of cluster members. Those were then matched with the observed targets by Kepler. After extensive data preparation that involved all stars observed in the campaign, we successfully constructed light curves for the target sample that are free of the systematics that typically plague K2 observations. We compare the observed distribution with models of stellar spindown, and with those for NGC6819, a similarly old, but much more distant cluster for which Kepler-based rotation periods are also available. We also discuss the implications of these results for stellar ages using gyrochronology.

How underestimated are Zeeman-doppler imaging based torque estimates?

Victor See (1); Lisa Lehmann (2); Sean Matt (3); Adam Finley (4)

(1) University of Exeter; (2) University of Toulouse; (3) University of Exeter; (4) University of Exeter

Low-mass stars are known to spin-down over their main sequence life-times due to braking from magnetised winds. A key ingredient to estimating angular momentum-loss rates is the stellar magnetic field strength and geometry. These are parameters that Zeeman-Doppler imaging (ZDI) can provide. Although ZDI cannot recover the magnetic field associated with small-scale fields, this has not been thought to be a problem since the spin-down torque is dominated by large-scale magnetic fields. However, recent work indicates that ZDI also underestimates the magnetic flux in the large-scale fields. In this talk, I will discuss the amount by which torque estimates based on ZDI maps may be underestimated by.

New Rotation Activity Constraints on a survey of Mid-to-Late M-Dwarfs

Thomas M. Boudreaux (1); Elisabeth R. Newton (2); Jonathan Irwin (3); David Charbonneau (4); Nicholas Mondrik (5)

(1) Dartmouth College; (2) Dartmouth College; (3) Harvard-Smithsonian Center for Astrophysics; (4) Harvard-Smithsonian Center for Astrophysics; (5) Harvard University

In the canonical formulation of stellar magnetic dynamo theory, the tachocline in partially convective stars serves to arrange small scale randomly oriented fields into a large scale coherent field. Mid-to-late M dwarfs are fully convective and therefore classical dynamo theory would predict little to no observable large scale field structure; however, they show strong, global magnetic fields and markedly high levels of magnetic activity. An open question therefore is by what mechanism fully convective M dwarfs generate and maintain these magnetic fields. Mid-to-late M dwarfs empirically show tight correlations between rotation rates and magnetic activity, with Ca II H&K strengthening with rotation rate up to a saturation threshold. Such a correlation is consistent with elements of classical dynamo theory. We use data from Magellan Inamori Kyocera Echelle (MIKE) Spectrograph to measure R'HK values for 53 spectroscopically identified M dwarfs. These stars span the fully convective boundary and have rotation periods ranging from days to months. Here we present a first look at the rotation–activity relationship as traced through these data. Better rotation–activity constraints will ultimately allow for more complete stellar dynamo models, capable of explaining magnetic activity in stars both with and without a tachocline.

General trends in winds of M dwarfs and the case of the planet-hosting star GJ 436

Amanda L. Mesquita; Aline A. Vidotto

Trinity College Dublin

M dwarf stars are currently the main targets in searches for potentially habitable planets. However, their winds have been suggested to be harmful to planetary atmospheres. We perform a one-dimensional magnetohydrodynamic parametric study of winds of M dwarfs that are heated by dissipation of Alfvén waves. These waves are triggered by sub-surface convective motions and propagate along magnetic field lines. We find that our winds reach isothermal temperatures very quickly with mass-loss rates proportional to base density square. We compare our results with Parker wind models and find that, although both models agree in a thermally driven regime, in the magnetically driven regime, the Parker wind underestimates the terminal velocity by around one order of magnitude and mass-loss rate by several orders of magnitude. We apply our model to the planet-hosting star GJ 436 and find, from X-ray observational constraints, $\dot{M} < 7.6 \times 10^{-15}\, M_{\odot}$ yr^{-1}.

Magnetic braking of accreting T Tauri stars: Effects of rotation, disk density, and dipolar field strength

Lewis G. Ireland (1); Claudio Zanni (2); Sean P. Matt (3)

(1) Department of Physics and Astronomy, University of Exeter, Stocker Road, Exeter, EX4 4QL, UK; (2) INAF - Osservatorio Astrofisico di Torino, Strada Osservatorio 20, 10025 Palermo, Italy; (3) Department of Physics and Astronomy, University of Exeter, Stocker Road, Exeter, EX4 4QL, UK

The rotational evolution of accreting pre-main-sequence stars is influenced by its magnetic interaction with its surrounding circumstellar disk. Using the PLUTO code, we perform 2.5D magnetohydrodynamic, axisymmetric, time-dependent simulations of star-disk interaction—with an initial dipolar magnetic field structure, and a viscous and resistive accretion disk—in order to model the three mechanisms that contribute to the net stellar torque: accretion flow, stellar wind, and magnetospheric ejections (periodic inflation and reconnection events). We investigate how changes in the stellar magnetic field strength, rotation rate, and initial disk/corona density contrast, affect the net stellar torque. All simulations are in a net spin-up regime. We parameterize the three stellar

torque contributions, allowing for the prediction of the net stellar torque for our parameter regime, and the possibility of investigating spin-evolution using 1D stellar evolution codes. The presence of an accretion disk appears to increase the efficiency of the stellar wind spin-down torque contribution, compared to those from isolated stars. A stellar wind with a mass loss rate of $\approx 1\%$ of the mass accretion rate is capable of extracting $\lesssim 50\%$ of the accreting angular momentum. These simulations suggest that achieving spin equilibrium in a representative T-Tauri case within our parameter regime, e.g., BP Tau, would require a stellar wind to extract $\approx 20\%$ of the mass accretion rate.

Moderate Resolution Spectroscopy of Directly Imaged Planets

Kielan K. Wilcomb (1); Quinn M. Konopacky (2); Travis S. Barman (3); Christopher Theissen (4); Jean-Baptiste Ruffio (5); Marshall Perrin (6); Justin Otor (7); Laci Brock (8); Bruce Macintosh (9); Christian Marois (10)

(1) Center for Astrophysics and Space Sciences, University of California San Diego; (2) Center for Astrophysics and Space Sciences, University of California San Diego; (3) Lunar and Planetary Laboratory, University of Arizona; (4) Center for Astrophysics and Space Sciences, University of California San Diego; (5) California Institute of Technology; (6) Space Telescope Science Institute; (7) Space Telescope Science Institute; (8) Lunar and Planetary Laboratory, University of Arizona; (9) Kavli Institute for Particle Astrophysics and Cosmology, Stanford University; (10) NRC Herzberg Astronomy and Astrophysics

Direct imaging of exoplanets has revealed a population of Jupiter-like objects that orbit at large separations (∼10-100 AU) from their host stars. These planets, with masses of ∼2-14 M_{Jup} and temperatures of ∼500-2000 K, remain a problem for the two main planet formation models—core accretion and gravitational instability. Observations that probe the elemental abundances in the atmospheres of these young gas giants can potentially shed light on their formation pathways. We present results from our ongoing survey of directly imaged planets with moderate (R∼4000) spectral resolution. We are making use of OSIRIS on the W.M. Keck I 10 meter telescope, which offers some of the best spectra to-date for directly imaged substellar companions. Thus far, we have observed nine companions in the K band (∼2.2 μm), including the "super-Jupiter" Kappa Andromeda b (Kappa And b). Our spectra reveal resolved molecular lines from water and CO, allowing for the derivation of atmospheric properties such as temperature, surface gravity, metallicity, and C/O ratio. In particular, we confirm that Kappa And b has a low surface gravity, consistent with a young age and mass near the deuterium burning limit. We provide an update on our survey, which will provide the most comprehensive look at young companion atmospheric properties to-date. But, our knowledge of exoplanet and substellar atmospheres is limited by the wavelength coverage of moderate resolution spectroscopy of these objects. The upcoming James Webb Space Telescope (JWST) instrument, NIRSpec, will offer wavelength coverage that spans 1 μm - 5 μm at a resolution of R ∼ 2,700. This could provide more complete coverage of CH_4, CO, and CO_2 absorption features. Measurements across this wavelength range would improve surface gravity and effective temperature estimates, our understanding of non-equilibrium chemistry and would be comparable to the resolution of our OSIRIS directly imaged planet library. We are simulating NIRSpec data cubes with substellar companion models based on our ground-based data and constructing PSF subtraction algorithms for this data. This will allow us to rapidly analyze JWST data once it launches, providing a resource to the entire community.

Constraining stellar CMEs with optical spectroscopy

Petra Odert (1); Martin Leitzinger (2); Eike W. Guenther (3); Petr Heinzel (4)

(1) Institute of Physics/IGAM, University of Graz, Austria; (2) Institute of Physics/IGAM, University of Graz, Austria; (3) Thüringer Landessternwarte Tautenburg, Germany; (4) Astronomical Institute, Czech Academy of Sciences, Ondřejov, Czech Republic

Our knowledge on coronal mass ejections (CMEs) on stars other than the Sun is still sparse. However, during past observations, some optical spectra showed asymmetrically broadened wings and/or transient extra emissions in chromospheric lines during or after flare events, commonly interpreted as signatures of prominence eruptions, which are closely related to CMEs on the Sun. Dedicated searches for these signatures have, however, mostly yielded non-detections. Here we present a semi-empirical model which combines predictions of intrinsic stellar CME rates with simple radiative transfer calculations in the Balmer lines. We find that typical observations have most likely been too short and/or they had a too low signal-to-noise ratio to detect CMEs. We predict the minimum observing time to detect CMEs in the Balmer lines for stars with different spectral types and activity levels.

The orbits of the speckle interferometric binaries. Problem systems.

Arina Mitrofanova; Vladimir Dyachenko; Anatoly Beskakotov; Yuri Balega; Alexander Maksimov; Denis Rastegaev

The Special Astrophysical Observatory of the Russian Academy of Sciences (SAO RAS)

The study of binary stars with low-mass components is one of the areas of application of speckle interferometry. The components of such systems are late-type main sequence stars. Despite the fact that to date our knowledge of parallaxes of binaries has been significantly improved thanks to Gaia DR2, problems remain in determining of the fundamental parameters of some of them. We present the results of long-term monitoring of speckle interferometric binaries HIP 14524, HIP 16025, HIP 28671, HIP 46199. Observations were carried out at the BTA SAO RAS using a speckle interferometer based on EMCCD (Maksimov et al., 2009) in 2007-2019. New or improved orbital solutions were obtained for the systems studied using new and previously published data. When determining the fundamental parameters, certain problems were identified related to the use of Hipparcos and Gaia parallaxes. The mass sums found by the two independent methods differ significantly from each other. This problem and the reasons for its occurrence are discussed.

The orbits of the speckle interferometric binaries. Long-term monitoring at BTA SAO RAS.

Anatoly Beskakotov; Arina Mitrofanova; Vladimir Dyachenko; Yuri Balega; Alexander Maksimov; Denis Rastegaev

The Special Astrophysical Observatory of the Russian Academy of Sciences (SAO RAS)

The study of binary stars with low-mass components is currently undergoing its ascent due to the Gaia mission. The high-precision positional parameters obtained by the Gaia mission will allow for the construction of the orbits of millions of such objects. Together with the well-known orbital solutions based on long-term monitoring, new data will significantly improve our knowledge about such objects. Therefore, in anticipation of the release of Gaia DR3, we present the results of long-term monitoring of speckle interferometric binaries HIP 18856, HIP 47791, HIP 53731, HIP 60444, HIP 61100, HIP 73085. Observations were carried out at the BTA SAO RAS using a speckle interferometer based on EMCCD (Maksimov et al., 2009) in 2007-2019. New observational data made it

possible to improve the already known orbital solutions or to obtain them for the first time. The fundamental parameters of objects obtained using the orbital parameters and parallaxes of Hipparcos and Gaia are in good agreement with each other.

On statistical properties of the solar coronal jets and their precursors

Salome R. Bagashvili (1); Bidzina M. Shergelashvili (2); Darejan R. Japaridze (3); Vasil Kukhianidze (4); Stefaan Poedts (5); Teimuraz V. Zaqarashvili (6); Maxim L. Khodachenko (7); Patrick De Causmaecker (8)

(1) Evgeni Kharadze Georgian National Astrophysical Observatory; (2) Center for Mathematical Plasma Astrophysics, Department of Mathematics, KU Leuven; (3) Space Research Institute, Austrian Academy of Sciences; (4) Combinatorial Optimization and Decision Support, KU Leuven Campus Kortrijk; (5) Institute of Physics, IGAM, University of Graz.

A set of 23 observations of solar coronal jet (CJ) events has been investigated using the data from the Atmospheric Imaging Assembly (AIA) on board of the Solar Dynamic Observatory (SDO). The characteristic properties and parameters of CJs were evaluated. The focus was on the temporal evolution of the brightness before and during coronal jet events. In the absolute majority of the investigated cases, CJs were preceded by the minor precursor disturbances in the mean intensity curves. The precursor was identified in 20 out of 23 cases. The analysis of precursors internal structure revealed an oscillatory-like behavior with characteristic periods approximately 3-4 minutes. The smaller modulation of the oscillation periods is also observed. We assume that along with the conventionally accepted scenario of bright point evolution certain MHD oscillatory and wavelike motions can be excited and these can take an important place in the observed dynamics of CJs. These quasi-oscillatory phenomena might play the role of links between different epochs of the CJ ignition and evolution.

Determination of Fundamental Atmospheric Properties of M-Dwarfs

Aishwarya Iyer; Michael Line

Arizona State University

About 70% of stars in the Milky Way galaxy are M-dwarfs. They span a range of low masses (0.08 - 0.6 solar mass), have faint luminosities (less than 5% solar luminosity), and temperatures ranging between 2500 K - 4000 K, facilitating molecule formation throughout their atmospheres. Standard stellar analysis methods to accurately characterize them have thus far proved challenging—in not correctly accounting for vast variations in their atmospheric structures. Our modeling framework will determine fundamental atmospheric properties of M-dwarfs with a two-pronged approach: a physically motivated self-consistent radiative-convective model grid with up-to-date opacities, constrained by thermo-chemical and hydrostatic equilibrium, radiative and convective transport as well as a data-driven Bayesian retrieval technique. We will leverage the broadband molecular absorption features occurring in low-resolution M-dwarf spectra (from SpeX Prism Library) and use them to our advantage in acquiring robust constraints on the effective temperature, surface gravity and bulk chemical properties of M-dwarf atmospheres. Our approach lies in the interface between the standard self-consistent prescription for modeling stellar atmospheres and an assumption-free data-driven retrieval method, where new physical intuition can be obtained about our understanding of low-mass stars.

Evolutionary models for ultracool dwarfs with CLES

Catarina S. Fernandes (1); Valérie Van Grootel (2); Sébastien J. A. J. Salmon (3); Bernhard Aringer, Adam J. Burgasser, Richard Scuflaire, Pierre Brassard (4)

(1) Université de Liège; (2) University of Geneva: Università di Padova; (3) University of California San Diego; (4) Université de Montréal

Ultracool dwarfs are excellent targets when searching for transiting earth-like exoplanets. Precise estimates of the host parameters are fundamental to constraining the physical properties of orbiting exoplanets. We have extended our evolutionary code Code Liégeois d' Evolution Stellaire to the ultracool dwarf regime. We include relevant equations of state for H, He, as well as C and O elements to cover the temperature-density regime of Ultracool dwarfs interiors. For various metallicities, we couple the interior models to two sets of model atmospheres as surface boundary conditions. We present some key results which also include a set of grids spanning across different metallicities to study the physical properties and evolution for these objects.

Characterizing Pulsed Accretion Signatures In Young Star Systems

Lauren Biddle (1); Joe Llama (2); Andrew Collier Cameron (3); Moira Jardine (4); Lisa Prato (5)

(1) Lowell Observatory/Department of Astronomy and Planetary Science, Northern Arizona University; (2) Lowell Observatory; (3) SUPA, School of Physics and Astronomy, University of St. Andrews; (4) SUPA, School of Physics and Astronomy, University of St. Andrews; (5) Lowell Observatory

Planets that orbit young stars are difficult to detect primarily because of the extreme variability of their parent star. Classical T Tauri stars in particular are subject to additional variability caused by the accretion of disk material onto the star. Despite the difficulties that accretion signatures can present for traditional planet-finding techniques, modulated accretion signals may aid in the identification of planetary-mass companions. The young ($\sim$2 Myr) classical star system, CI Tau, is of particular interest in this context because it is host to a non-transiting hot Jupiter known to drive pulsed accretion on the timescale of the planetary orbit. We present our analysis of photometric accretion signatures in young star systems and discuss the utility of these data in flagging potential planetary-mass candidates for RV followup.

Undiscovered spectroscopic binaries among bright cool stars

D. Jack; M. A. Hernandez Huerta; K.-P. Schroeder

Universidad de Guanajuato

We have discovered that several bright stars (m_V < 7.66 mag) are misclassified in SIMBAD and are actually spectroscopic binaries. The majority are cool giant stars.

Using the 1.2 m TIGRE telescope with the optical HEROS spectrograph (R = 20,000) and the recently published Gaia DR2 we performed an aimed search for bright spectroscopic binary stars. In our sample of 19 candidate stars, all turned out to be binary systems. So far, we were able to determine the orbital parameters of five stars that have a period of less than one year. The minimal masses of the secondary stars were also determined. We are continuing our observation campaign in order to find more spectroscopic binary stars and determine their orbital parameters and hope to present new results at the CS 21 conference.

A search for CMEs on solar-like stars in archival data

Martin Leitzinger (1); Petra Odert (2); Robert Greimel (3); Krisztian Vida (4); Levente Kriskovics (5); Eike W. Guenther (6); Heidi Korhonen (7); Florian Koller (8); Arnold Hanslmeier (9); Zsolt Kövari (10); Helmut Lammer (11)

(1) University of Graz, Institute of Physics, IGAM; (2) Konkoly observatory, MTA, CSFK; (3) Thüringer Landessternwarte; (4) European Southern Observatory; (5) Dark Cosmology Centre, Niels Bohr Institute, University of Copenhagen; (6) Space Research Institute, Austrian Academy of Sciences

In the last years efforts have been made to determine parameters of stellar coronal mass ejections (CMEs), on the one hand via acquiring dedicated observing time at telescopes and on the other hand via searching data archives. Here we present a search for CMEs on solar-like stars using optical spectroscopic data from the Polarbase and ESO HARPS Phase 3 archives. For detecting stellar CMEs we use the signature of filaments/prominences being ejected from a star, which is Doppler-shifted emission/absorption occurring on the blue side of Balmer lines, as filaments/prominences are very pronounced in Balmer lines. Using more than 3700 hours of on-source time of 425 stars we aim for a statistical determination of CME parameters, such as projected velocity, occurrence frequency, and mass. The target stars are nearby objects and consist of F-K main-sequence stars of various ages. We find no signature of CME activity and a very low level of flaring activity (10 out of 425 stars). Comparing this to results from the Kepler mission, the fraction of flaring stars is more or less consistent. Comparing extrapolated Hα flare rates to the sparse detection of flares reveals that we could have detected more flares. We therefore determined the full-disk Hα signal of one of the strongest solar flares in the last solar cycles. This showed that we would have needed data with higher S/N to detect such a flare in our data. Finally, we compared the observed upper limits of CME rates of our target stars to modelled CME rates. The modelled CME rates are mostly below the observationally determined upper limits, indicating that most on-source times per star were too short to detect stellar CMEs with this method. We conclude that biases naturally introduced by using archival data, as well as a a low level of activity of the target stars may explain the sparse detection of flares and the non-detecion of CMEs on those stars.

M dwarf stellar characterization from Habitable Zone Planet Finder spectra

R. Terrien for the HPF Team

Carleton College

Exoplanet-finding missions such as TESS and PLATO are expected to reveal hundreds of exoplanets around nearby M dwarfs, which will be targeted for follow-up characterization by high-resolution spectrographs around the world. Placing the resultant dynamical (planetary mass, orbital configuration) findings in context benefits from a precise understanding of stellar properties such as composition, activity level, and age. However, precise and broadly-applicable methods for measuring these properties of M dwarfs remain elusive, largely due to their complex spectra, atmospheres, and structures. We present here a library of $\sim$70 well-characterized M dwarf stars observed with the Habitable Zone Planet Finder (HPF), a high-resolution spectrograph that operates in the near-infrared ($\sim$800-1300nm), optimal for mid-to-late type M dwarfs. We combine previously-determined elemental abundances, rotational velocities, and activity levels with measured rotational velocities

and equivalent widths from HPF spectra to evaluate the efficacy of using HPF spectra to measure the stellar parameters of M dwarfs. In particular, we study the precision and accuracy of rotational velocity determination from these spectra, and the use of selected equivalent widths to establish elemental abundances beyond the baseline iron abundance. These results establish methodologies and limitations for use of this M dwarf library for the characterization of M dwarfs with HPF.

Evolving Chromospheres of M Dwarfs

K. G. Carpenter (1); V.S. Airapetian (2); K. France (3); G. Kober (4); S. Peacock (5); G. Rau (6); K. Nielsen (7)

(1) NASA's GSFC; (2) NASA's GSFC, Univ. of Colorado, CUA@GSFC, NASA's GSFC/LPL, CUA@GSFC, CUA@GSFC

Recent observations of M dwarfs suggest many of them harbor close-in exoplanets of various sizes: from Earth-like to gas giant planets. These stars possess intense magnetic fields, the source of chromospheric and coronal heating and generate energetic flares with high fluxes of X-ray and Extreme UV (EUV) radiation. The chromospheres and coronae of M dwarfs, the sites of energetic emissions in the FUV and EUV, are thus important for understanding their impact on atmospheric escape from close-in exoplanets in habitable zones. Thus, chromospheric and coronal signatures of M dwarfs that provide insights on the EUV fluxes are a critical piece of the habitability puzzle. Here, we describe the results of HST/STIS and COS observations of chromospheric and coronal lines from $\sim$60 early-to-late M dwarf stars with rotation periods between 0.2-130 days during quiescent and flaring states. We will search in the 60 stars for the fully resolved profiles of FUV O IV (1401.2 A) and Si IV (1393.7 and 1402.8 A) chromospheric emission lines. These lines provide information about non-thermal broadening introduced by large-scale turbulence, while intense line wings suggest anisotropic turbulence due to Alfven waves propagating upward from the chromosphere. The ratios of O IV and Si IV emission lines also suggest denser chromospheres and transition regions than that observed on the Sun. We use these data to estimate the energy available in the stellar chromosphere and to determine correlation with the coronal Fe XII 1242 A and Fe XXI 1354 A emission lines intensities. These observations are used to constrain our chromospheric models and predict non-LTE model spectra of young and mature M dwarfs. Finally, we discuss the impact of the resulting ionizing radiation environment on the erosion of planetary atmospheres, and thus on the habitability criteria to be used in the selection of future JWST exoplanetary targets.

Studying the atmosphere of the close binary star system AADor with simulation code phoenix/1D

Fiona Prodöhl; Peter H. Hauschildt

Universität Hamburg

Synthetic spectra from model atmospheres are frequently used in the analysis of observed spectroscopic and photometric data. For the most part, the models are sufficiently detailed to test the current theoretical understanding of stellar and sub-stellar mass objects at various stages in their evolution. However, the vast majority of model atmospheres are constructed under the assumption that the nearest stellar neighbor is so far away that it can be safely ignored. This assumption, while safe for most stars, fails for many short period binaries. A number of binary systems have orbital separations small enough so that one of the binary members is significantly heated by its companion. In order for synthetic spectra to be useful in such cases, the standard "isolated" modeling

approach must be replaced by one that includes the effects of irradiation. The AADor system is an excellent example of a well-studied non-mass transferring Post-common envelope binary system. Its members are a sdOB-type primary and an extremely low mass secondary. This work is aiming to provide better theoretical models by using spherical models. We investigate how several 1D models combined to a 1.5D model can represent this system. Our future aim is to compare these results to a phoenix/3D model that is able to include effects of irradiation closer to the terminator where transmitting light plays a big role.

Orbital Architectures of Stellar, Brown Dwarf, and Planetary Companions Around Nearby M Dwarfs

Eliot Halley Vrijmoet (1); Todd J. Henry (2); Andrew A. Couperus (3); Wei-Chun Jao (4); Andrei Tokovinin (5)

(1) RECONS Institute & Georgia State University; (2) RECONS Institute; (3) RECONS Institute & Georgia State University; (4) Georgia State University; (5) Cerro Tololo Inter-American Observatory

Comprising three out of every four stars, the M dwarfs form a unique sample that can host companions orbiting at Solar System scales and spanning a factor of 100,000 in mass. Targeting 120 M dwarf binaries within 25 parsecs, we are determining the period vs. eccentricity distribution for M dwarf stellar companions with orbital periods up to 6 years and semimajor axes up to 5 AU. This range is enabled by our combination of multiple observational methods: long-term astrometry from our RECONS program at the CTIO/SMARTS 0.9m is characterizing orbits on decades-long timescales, while our speckle interferometry survey at SOAR with HRCAM+SAM maps shorter orbits of systems identified from Gaia DR2, while also providing resolutions and masses for our long-period astrometric binaries. We will supplement these results with orbits from the literature, from both radial velocity and high-resolution imaging surveys, to ensure that our sample is rich with companions of all types orbiting within 5 AU. Initial results of this work so far suggest a notable paucity of M dwarf stellar companions with circular orbits greater than 5 years in period, showcasing the additional leverage provided by this combination of long-term astrometry and high-resolution imaging. Ultimately, when compared to the orbits of brown dwarf and planetary companions, such structures will be critical to understanding the formation mechanisms of these systems.

Chemical Tagging As Told By Wide Binaries and Comoving Pairs: Promise and Limitations

Julio Chanamé (1); Jeff Andrews (2); Marcel Agüeros (3)

(1) Pontificia Universidad Católica de Chile; (2) Northwestern University; (3) Columbia University

Stars of a common origin are thought to have similar, if not nearly identical, chemistry. Chemical tagging, as a tool for Galactic archaeology, seeks to exploit this assumption in order to identify Milky Way subpopulations through their unique chemical fingerprints. The components of wide binaries are, by definition, stars with common origins, which makes them ideal systems in which to test the underlying assumption behind the concept of chemical tagging. Moreover, the level to which the components of wide binaries are found to be chemically homogenous/heterogeneous provides the calibrations required to inform any chemical tagging attempts. Current and upcoming wide-field photometric, astrometric, and spectroscopic surveys all clearly converge in the study and exploitation of wide binaries for a large variety of Galactic astronomy problems. I will provide a review of what we know about the degree of chemical homegeneity/heterogeneity of the components of

wide binaries and comoving pairs (which pose additional challenges than wide binaries), with an emphasis on the recent attempts to address some of the above questions on Galactic chemical tagging via the detailed study of populations of wide binaries and comoving pairs as identified with Gaia.

Age-Activity relation for M dwarfs using H_α equivalent widths

Rocio Kiman (1); Jacqueline Faherty (2); Kelle Cruz (3); Siyi Xu (4); Jonathan Gagné (5); Sarah Schmidt (6); Ruth Angus (7); Daniella Bardalez Gagliuffi (8); Emily Rice (9)

(1) Graduate Center, CUNY, New York, NY, US & American Museum of Natural History, New York, NY, US; (2) American Museum of Natural History, New York, NY, US; (3) CUNY Hunter College, New York, NY, US & American Museum of Natural History, New York, NY, US & Center for Computational Astrophysics, Flatiron Institute, New York, NY, US; (4) Gemini Observatory, Hilo, HI, US; (5) University of Montreal, Montréal, Canada; (6) Leibniz-Institut für Astrophysik - Potsdam (AIP), Potsdam, Germany; (7) American Museum of Natural History, New York, NY, US & Center for Computational Astrophysics, Flatiron Institute, New York, NY, US & Columbia University, New York, NY, US; (8) American Museum of Natural History, New York, NY, US; (9) CUNY Macaulay Honors College, NY, US & American Museum of Natural History, New York, NY, US

Ages of low mass stars, particularly for M dwarfs, cannot be obtained with the same methods used for solar type stars because stellar evolution models break down for fully convective stars. Therefore, empirical and statistical methods are required to constrain the ages of M dwarfs. We are building a robust Bayesian algorithm to infer ages of M dwarfs from two age indicators: 1) magnetic activity, as indicated by Hα equivalent widths, obtained from two catalogs from the Sloan Digital Sky Survey, and 2) full kinematics from Gaia DR2. In order to anchor this method, the age-activity relation for Hα is needed. We compiled a sample of M dwarfs age calibrators for which we could get an age because they belong to known moving groups or because they have a white dwarf companion. I will present this sample of age calibrators and the best fit to the age-activity relation. I will also present mdwarfdate, the code to infer ages and some preliminary results with simulated data.

Lunar occultations in the spectrum at the 6-m telescope of the SAO RAS. Method and first resolved giants.

V. Dyachenko (1); A. Richichi (2); Yu. Balega (3); A. Beskakotov (4); A. Maksimov (5); A. Mitrofanova (6); E.Shmaylova (7)

(1) SAO RAS, Russia; (2) INAF, Italy; (3) SAO RAS, Russia; (4) SAO RAS, Russia; (5) SAO RAS, Russia; (6) SAO RAS, Russia; (7) SPbSU, Russia

The determination of stellar radii, the study of the physics of their atmospheres and circumstellar matter is one of the most difficult tasks in astrophysics of high angular resolution.The lunar occultations method provides an angular resolution of the order of 1 millisecond of the arc, which is comparable with the limits of optical and near infrared long-base interferometry. In order to maximize its capabilities in 2018, we developed a scheme that allows obtaining photometric curves of occultations in the spectrum. The system provides a range of 340 nm with a spectral resolution of about 10 nm in the visible and near infrared region. In 2019, the first data were obtained on the 6-m telescope of SAO. The results of observations of a number of giant stars of various types are presented. The contribution of circumstellar matter and dust to the observed diameter variations is discussed.

Cool Stars and Planetary Systems Research at the University of Southern Queensland

Brad Carter for the Centre of Astrophysics

University of Southern Queensland

USQ research focuses on the shared evolution of stars and their planetary systems. Projects include stellar activity, magnetic field and wind studies, exoplanet surveys, and planetary system modelling. USQ's Mt Kent Observatory hosts the MINERVA-Australis exoplanet radial velocity facility providing TESS follow-up spectroscopy, Shared Skies Partnership telescopes providing exoplanet transit photometry, and a new SONG asteroseismology node.

KIC 2852961 – a superflaring red monster in the Kepler field

Zsolt Kővári (1); Katalin Oláh (2); Maximilian N. Günther (3); Krisztián Vida (4)

(1) Konkoly Observatory, Research Centre for Astronomy and Earth Sciences, Budapest, Hungary; (2) Konkoly Observatory, Research Centre for Astronomy and Earth Sciences, Budapest, Hungary; (3) Department of Physics, and Kavli Institute for Astrophysics and Space Research, Massachusetts Institute of Technology, Cambridge, MA 02139, USA; (4) Konkoly Observatory, Research Centre for Astronomy and Earth Sciences, Budapest, Hungary; (5)

Superflares on giant stars have up to 100,000 times more energy than the high energy solar flares. However, it is disputed, whether scaling up a solar-type dynamo could explain such a magnitude difference. We investigate the flaring activity of KIC 2852961, a late-type spotted giant. We seek for flares in the Kepler Q0-Q17 datasets by an automated technique together with visual inspection. Flare occurence rate and flare energies are analyzed and compared to flare statistics of different targets with similar flare activity at different energy levels. We find that the flare energy distribution of KIC 2852961 does not seem to be consistent with that of superflares on solar-type stars. Also, we believe that in case of KIC 2852961 spot activity should have an important role in producing such superflares.

Tuning spin evolution models to cluster rotation data

Sean Matt; Tim Naylor

University of Exeter

Rotation rates of stars $\leq$ 1.3 $M_{\odot}$ give important insights into stellar evolution and the physics of stellar magnetic activity and winds. Combined with a spin evolution model, observed rotation rates can constrain stellar ages (particularly on the main sequence where rotation rates are observed to change by an order of a magnitude) and stellar wind properties. We have adapted the robust τ^2 statistical technique to allow us to fit physical spin evolution models to entire cluster rotation datasets in the period-mass plane. The τ^2 method can also fit models to multiple cluster rotation datasets simultaneously, allowing us to constrain the model across several stages in its evolution. We find that (i) for a given spin model, we can statistically determine gyrochronology ages for clusters, (ii) we can constrain the physics of stellar winds by fixing the age and varying the stellar wind parameters of the model, (iii) using different methods to convert observables to masses significantly impacts the best-fit parameters, and (iv) using the observed distribution of the $\sim$ 8 Myr old Upper Sco as

an initial condition leads to a significantly improved fit, highlighting the importance of model initial conditions.

Li-rich giant stars under scrutiny

Bernardo F. O. Gonçalves; Jefferson S. da Costa; Leandro de Almeida; Matthieu Castro; José Dias do Nascimento, Jr.

UFRN - Federal University of Rio Grande do Norte

We present a study of the evolutionary state of some classical lithium-rich giant stars based on the Gaia DR2 parallaxes and photometry. We also investigate the chromospheric activity, the presence of a surface magnetic field, and the radial velocity for our sample stars. We analyzed both archive and new data. We gathered archive spectra form the several instruments, mainly ELODIE and NARVAL, and we added new data from our observations with the spectrograph MUSICOS. We applied the Least-Squares Deconvolution technique to obtain Stokes V and Stokes I mean profiles to compute longitudinal magnetic field for a subset. Moreover, for the same subset, we analyzed the Ca II H and K emission lines to calculate the S-index. We also derived atmospheric parameters and Li abundances for all eighteen stars of our sample. We found that stars that were previously classified as RGB may actually be at a different evolutionary state. Furthermore, we identified that most stars in our sample with detection of surface magnetic field show at least moderate rotation velocities, but nonetheless, we could not detect a magnetic field in two fast rotators. Due to our small sample of magnetic giants, it is difficult to determine if the presence of surface magnetic field and the Li-rich giant phenomena could be somehow linked. The large variation of the radial velocity of part of our sample indicates that some of them might have a binary companion, which may change the way we look at the Li problem in giant stars.

The violent environment of RCW38 and its impact on substellar formation efficiency

Karolina Kubiak (1); Koraljka Muzic (2); Victor Almendros Abad (3); Joana Ascenso (4); Rainer Schoedel (5)

(1) Centro de Astrofísica e Gravitação - CENTRA, Universidade de Lisboa; (2) Centro de Astrofísica e Gravitação - CENTRA, Universidade de Lisboa; (3) Centro de Astrofísica e Gravitação - CENTRA, Universidade de Lisboa; (4) Universidade do Porto; (5) Instituto de Astrofísica de Andalucía; (6)

Richly populated massive young clusters are important laboratories to probe a variety of unsolved questions related to star, brown dwarf, and cluster formation. RCW38, located in the Vela star-forming complex, is one of the densest and most massive young stellar clusters within 4 kpcs. It is at least twice as dense as Orion Nebula Cluster and orders of magnitude denser than local star-forming regions. RCW38 hosts dozens of massive OB star candidates. In this contribution, I will present the deepest photometric study of the cluster captured by the HAWK-I/GRAAL infrared imager at the VLT. With our data, we will look for the effects that such a violent birth environment may have on the formation efficiency of very-low mass stars and sub-stellar objects, and test whether the previously reported peculiarities in the IMF may be due to mass segregation. I will summarise the implications of these results for our understanding of low mass stars and sub-stellar formation processes.

Dynamics of the Convective Turbulence in the Solar Convection Cells Studied by the Spectral Line Broadening and Asymmetry

Ryohtaroh T. Ishikawa (1); Yukio Katsukawa (2); Takayoshi Oba (3); David Orozco Suárez (4); Masahito Kubo (5); Yoshinori Suematsu (6)

(1) SOKENDAI & National Astronomical Observatory of Japan; (2) National Astronomical Observatory of Japan; (3) Institute of Space and Astronautical Science/Japan Aerospace Exploration Agency; (4) Instituto de Astrofísica de Andalucía (CSIC); (5) National Astronomical Observatory of Japan; (6) National Astronomical Observatory of Japan

On the surface of solar-type starts, turbulent convective motions play an important role in creating magnetic structures, as well as in energy injection into the upper atmosphere. Although it is important to understand the turbulent nature of the stellar convection, it is difficult to observe the motions on a wide range of spatial scales, especially on the scales smaller than the convection cells. In the case of the Sun, however, we can spatially resolve the convection cells and can observe the small-scale turbulent motions using the spectral line broadening, which contains information on the flow field smaller than the spatial resolution of an instrument. In this study, we analyzed the spectral line profiles of the solar surface obtained using the Spectro-Polarimeter of the Hinode satellite, and newly found significant line broadening in fading process of the convection cells. To investigate the mechanism of the line broadening, we performed spectral line inversion and obtained the height dependence of the temperature, line-of-sight velocity, and microturbulence in the photosphere. We found that the turbulent motion of about 1km/s is required to explain the spectral line widths of the fading cells.

Discovery of a coordinated photospheric and X-ray activity cycle in the young Sun, ι Hor.

Gaitee A.J. Hussain (1); Julian David Alvarado Gomez (2); Eliana Amazo-Gomez (3); Jeremy Drake (4); Beate Stelzer (5); Jean-Francois Donati (6)

(1) European Southern Observatory (ESO); (2) Leibniz-Institute for Astrophysics Potsdam (AIP); (3) Max Planck Institute for Solar System Research (MPS); (4) Harvard-Smithsonian Center for Astrophysics; (5) Universität Tübingen; (6) IRAP

ι Horologii (ι Hor) is one of the youngest solar-type stars (625 Myr) to display a coronal activity cycle - as recently traced with XMM-Newton. The cycle itself has a period of 1.6 years, and is the shortest cycle found to date. We have traced the evolution of its large-scale magnetic field over two full activity cycles using spectropolarimetric data from the ESO 3.6-metre telescope and Zeeman Doppler Imaging. Our study shows that the surface radial magnetic field distribution reverses over 1.6 years and returns back to the original polarity after 2 activity cycles, as with the Sun. From an analysis of ι Hor's large scale field and a comparison with the Sun viewed at the same spatial scales, we find significant differences in the evolution of several other key parameters over the course of the cycle (e.g. axisymmetry, toroidal fraction, and complexity). We comment on what this reveals about the different underlying dynamo mechanisms.

The Perilous Lives of Planets in Binary Star Systems

Trent Dupuy (1); Daniel Huber (2); Erik Petigura (3); Travis Berger (4); Eric Gaidos (5); Michael Ireland (6); Andrew Mann (7); Aaron Rizzuto (8)

(1) Gemini Observatory; (2) University of Hawaii at Manoa; (3) University of California - Los Angeles; (4) University of Hawaii at Manoa; (5) University of Hawaii at Manoa; (6) Australian National University; (7) University of North Carolina - Chapel Hill; (8) University of Texas at Austin

The majority of solar-type stars form with binary companions, and they should profoundly sculpt the formation and evolution of planetary systems. However, most searches for extrasolar planets have concentrated exclusively on single stars, avoiding close binary systems where the companion might complicate the observations and analysis. I will discuss statistically robust samples that outline the influence of stellar multiplicity at different stages of the formation and evolution of circumstellar disks and planetary systems, especially by exploring the discovery space for binary companions on solar-system scales (5-50 AU) even around relatively distant stars (200-500 pc). I will also outline how the disk-hosting and planet-hosting binary samples are being dramatically expanded by results from Gaia DR2, including the identification of even very close binary systems from heightened scatter in the Gaia data. From the combined census of stellar multiplicity and protoplanetary disk occurrence in star-forming regions, binary companions have a ruinous effect upon protoplanetary disks at ages when disks are still ubiquitous among single stars and wide binaries. The corresponding disk fraction among close binaries is suppressed by a factor of 3-4. The corresponding census of stellar multiplicity and transiting planetary systems at old ages, as assessed in the Kepler sample, shows a similar suppression rate among close binaries. However, some planetary systems do survive even in very dynamically perilous configurations, and I will outline the factors that potentially contribute to planetary survival and destruction. Finally, I will discuss how these results change the interpretation of planet formation and disk dissipation around single stars, given that almost all of them appear to host disks for at least 2-3 Myr, and what this might mean for the timescales and mass budgets for assembling planetary systems.

Measuring stellar magnetic helicity density

K. Lund (1); M. Jardine (2); L. T. Lehman (3); D. H. Mackay (4); V. See (5); A. A. Vidotto (6); J.-F. Donati (7); R. Fares (8); C. P. Folsom (9); S. V. Jeffers (10); S. C. Marsden (11); J. Morin (12); P. Petit (13)

(1) SUPA, School of Physics and Astronomy, University of St Andrews, North Haugh, St Andrews, KY16 9SS, UK; (2) School of Mathematics and Statistics, University of St Andrews, North Haugh, St Andrews, KY16 9SS, UK; (3) University of Exeter, Department of Physics & Astronomy, Stocker Road, Devon, Exeter, EX4 4QL, UK; (4) School of Physics, Trinity College Dublin, the University of Dublin, College Green, Dublin-2, Ireland; (5) IRAP, Université de Toulouse, CNRS, UPS, CNES, 14 Avenue Edouard Belin, 31400, Toulouse, France; (6) Physics Department, United Arab Emirates University, P.O. Box 15551, Al-Ain, United Arab Emirates; (7) Institut für Astrophysik, Universität Göttingen, Friedrich-Hund-Platz 1, D-37077 Göttingen, Germany; (8) University of Southern Queensland, Centre for Astrophysics, Toowoomba, QLD, 4350, Australia; (9) LUPM, Université de Montpellier, CNRS, Place Eugène Bataillon, F-34095 Montpellier, France

Helicity is a fundamental property of a magnetic field but to date it has only been possible to observe its evolution in one star - the Sun. We provide a simple technique for mapping the large-scale helicity density across the surface of any star using only observable quantities: the poloidal and toroidal magnetic field components (which can be determined from Zeeman-Doppler imaging) and the stellar radius. We use a sample of 51 stars across a mass range of 0.1-1.34 $M_{\odot}$ to show how the helicity density relates to stellar mass, Rossby number, magnetic energy and age. We find that the large-scale helicity density increases with decreasing Rossby number Ro, peaking at Ro $\approx$ 0.1, with a saturation or decrease below that. For both fully- and partially-convective stars we find that the mean absolute helicity density scales with the mean squared toroidal magnetic flux density

according to the power law: $|\langle h\rangle| \propto \langle B_{\rm tor}^2\rangle^{0.86\pm0.04}$. The scatter in this relation is consistent with the variation across a solar cycle, which we compute using simulations and observations across solar cycles 23 and 24 respectively. We find a significant decrease in helicity density with age.

Dynamo drivers measured in Suns of different ages

Jörn Warnecke (1); Maarit J. Käpylä (2)

(1) Max Planck Institute for Solar System Research; (2) Aalto University & Max Planck Institute for Solar System Research

Solar-like stars are more active when they are young and rotate more rapidly, while as they age, they spin down and also become magnetically less active. Hence, rotation rate is usually a reasonably good tracer of the star's age. We used this fact to probe the dynamo mechanism over time in solar-like partially convective stars using 3D MHD global convection simulations with varying rotation rates, and measured the turbulent effects taking part in the dynamo mechanism using the test-field method. As a first result, we find that one of the most important contributions to the dynamo drivers, the α tensor increases for moderate rotation rates with Co$^0.5$ and levels off for rapid rotation. This behavior agrees with calculation of the kinetic α, if one considers the decrease of the convective scale with increasing rotation. Moreover, the α tensor becomes highly anisotropic for Co$\leq$1, α_{rr} dominates for moderate rotation (1<Co<10), and $\alpha_{\phi\phi}$ for rapid rotation (Co$\leq$10). The turbulent pumping effect is dominating the meridional transport of the magnetic field. Taking all dynamo effects into account, we find three distinct regimes. For slow rotation, the α and Rädler effects are dominating in presence of anti-solar differential rotation. For moderate rotation, α and Ω effects are dominant, indicative of $\alpha\Omega$ or $\alpha^2\Omega$ dynamos in operation, producing equatorward-migrating dynamo waves with the qualitatively solar-like rotation profile. For rapid rotation, an α^2 mechanism, with an influence from the Rädler effect, appears to be the most probable driver of the dynamo. Our study reveals the presence of a large variety of dynamo effects beyond the classical $\alpha\Omega$ mechanism, which need to be investigated further to fully understand the dynamos of solar-like stars.

X-ray Emission in Cepheids due to Shock Waves

S. P. Moschou (1); N. Vlahakis (2); J. J. Drake (3); N.R. Evans (4); H. R. Neilson (5); J. A. Guzik (6); J. ZuHone (7)

(1) Center for Astrophysics | Harvard & Smithsonian, USA; (2) University of Athens, Greece; (3) Center for Astrophysics | Harvard & Smithsonian, USA; (4) Center for Astrophysics | Harvard & Smithsonian, USA; (5) University of Toronto, Canada; (6) Los Alamos National Laboratory, USA; (7) Center for Astrophysics | Harvard & Smithsonian, USA

Cepheids are massive cool stars with variable emission triggered by their pulsation cycles. At minimum radius as the pulsation compression passes through Cepheids produce some well studied disturbances in their photospheric and chromospheric signatures. Cepheids were thought to be weak sources of X-rays, but recent studies discovered an X-ray variable signal in the light-curves of a handful of stars during the maximum radius phase. This variable X-ray emission was unexpected and currently there has not been any theory proposed that can explain the details of these observations. In this work, we use the modern astrophysical MHD code, Pluto, to simulate the Cepheid variability and assess the capability of pulsation-driven shocks to create a phase-dependent X-ray luminosity enhancement in these stars. We have run a number of hydrodynamic numerical simulations with a variety of initial and boundary conditions in order to explore the capability of shocks to produce the observed X-ray behavior in Cepheids. Finally we used the Simulated Observations of

X-ray Sources (SOXS) package to create synthetic or mock spectra for each simulation case and link our simulations to observables. We find that under specific conditions shocks are able to reproduce a phase dependent X-ray luminosity enhancement for pulsation driven outflow and discuss the implications of such a scenario on the Cepheid atmospheres and their mass loss.

Dynamical Masses of young visual binaries as test for pre-main-sequence evolutionary models

Rainer Köhler (1); Karolina Kubiak (2); Thorsten Ratzka (3)

(1) University of Vienna, Austria; (2) CENTRA, Lisbon, Portugal; (3) Planetarium im Museum am Schölerberg, Osnabrück, Germany

The mass is the most important parameter for the structure and evolution of a star. Therefore, empirical mass determinations are crucial for our understanding of stellar astrophysics. In particular, this is the case for low-mass pre-main-sequence stars, for which a number of evolutionary models with different mass predictions exist. The stellar masses and ages derived from these models form the basis for studies of, e.g., the Initial Mass Function, cluster ages, and disk lifetimes. It is therefore important to calibrate pre-main-sequence tracks with model-independent mass measurements. Orbits of binary stars offer one of only two ways to measure stellar masses directly, without relying on theoretical models. They are therefore valuable test cases for theoretical pre-main-sequence tracks. We are monitoring a number of young visual binaries that were discovered in the 1990s. Many of them show significant orbital motion by now, and it was possible to determine the orbit for some. We will present first results and show some interesting systems.

Youth assessment in near infrared spectra of brown dwarfs and very low mass stars: a case study of NGC2244

Víctor Almendros-Abad (1); Koraljka Muzic (2); André Moitinho (3); Alberto Krone-Martins (4); Karolina Kubiak (5)

(1) CENTRA, Faculdade de Ciencias da Universidade de Lisboa, Lisboa; (2) CENTRA, Faculdade de Ciencias da Universidade de Lisboa, Lisboa; (3) CENTRA, Faculdade de Ciencias da Universidade de Lisboa, Lisboa; (4) Donald Bren School of Information and Computer Sciences, University of California, Irvine; (5) CENTRA, Faculdade de Ciencias da Universidade de Lisboa, Lisboa

Studies of young brown dwarf populations are crucial to understand their formation mechanisms, but also to grasp all the channels through which star and planet formation processes may go. When searching for young brown dwarfs in star forming regions, the main obstacle is the determination of cluster membership, which cannot be established by photometry alone. Spectroscopic follow-up is an indispensable step to obtain robust samples of low-gravity, young members. I will present a new method for the analysis of very-low mass object spectra with spectral types between M2 and L2, using near-infrared H- and K-bands (1.4-2.4 μm). We define a new gravity-sensitive spectral index, which performs consistently well over the spectral range of interest, unlike any of the previously defined indices. We also evaluate the performance of machine learning methods for youth assessment using the entire object spectrum. Finally, we apply our methods to 140 KMOS/VLT spectra of very-low mass candidates in the 2 Myr old cluster NGC 2244, part of a bigger project that aims at testing the effects of the environment in substellar formation. We report the discovery of the first spectroscopically confirmed brown dwarfs located at kpc distances.

High-Resolution Model Spectra for Cool Stars: the Good, the Bad, and the Ugly

Yutong Shan; Ansgar Reiners; CARMENES Consortium

University of Goettingen

The growing availability of high-quality, high-resolution spectra for M-dwarfs has introduced unprecedented opportunities to characterize and understand these cool stars. Inferring reliable stellar properties such as temperature, metallicity, and elemental abundance patterns depends critically on correctly interpreting the data. This task is very often guided by model spectra, which involve many complex components. While state-of-the-art synthetic spectra show broad agreement with observed ones, many areas of mismatch persist. Using the latest CARMENES spectra (R $\sim$ 90000) as empirical benchmarks, we analyze shortcomings in modelling specific line features for several suites of synthetic spectra generated by popular codes. We also contrast with metallicity indicators in lower spectral resolution regimes, in particular those empirically calibrated to FGK binary companions. This is ongoing work with implications for the 'true' error bars on derived parameters for M-dwarfs, and will shed insight on how to improve cool star atmosphere models to meet demands of the near-future.

MML 48: A new pre-main sequence eclipsing binary in a triple system

Leslie Hebb (1); Yilen Gómez Maqueo Chew (2); Henrik.C. Stempels (3); Rachel A. Street (4); Max Brodheim (5)

(1) Hobart and William Smith Colleges; (2) UNAM; (3) Uppsala University; (4) LCO; (5) Hobart and William Smith Colleges

We present preliminary fundamental properties of the newly discovered pre-main sequence eclipsing binary, MML 48. The 16 Myr Upper Centaurus Lupus eclipsing system consists of a 1.3 $M_{\odot}$ primary star in a 2.0171 day orbit with a 0.27 $M_{\odot}$ secondary star. Our analysis is based on new and archival spectra and time-series photometry. From the spectroscopic analysis, we determined the temperature of the primary star to be 5386 $\pm$ 100 K, with the secondary star at a temperature of 3500 K on the Hyashi track. Both stars are enlarged significantly compared to their expected main sequence radii, and it is possible a third unresolved star in the system is causing changes to the epoch of the eclipses due to light travel time effects as the binary orbits the center of mass of the triple system. The properties of the MML 48 component in combination with those of MML 53, another PMS EB of the same age, provides a strong constraint on the 16 Myr old theoretical isochrone using four stars with masses ranging from $0.27 - 1.3\ M_{\odot}$.

Transiting, low-mass Companions to Kepler Objects of Interest

Suvrath Mahadevan; Chad Bender; SDSS-IV/APOGEE-2 Collaboration

Pennsylvania State University, University of Arizona

We report masses, radii, and ages estimates of 24 low-mass companions to Kepler objects of interest, with masses spanning the brown dwarf and M dwarf regime ($\sim 23 - 200\ M_J$). These objects were detected by the Kepler mission and observed spectroscopically as part of our ongoing project

with the Sloan Digital Sky Survey IV with the multiplexed Apache Point Observatory Galactic Evolution Experiment (APOGEE) near-infrared spectrograph. We have almost doubled the number of well-characterized objects with mass and radius measurements in this regime and, using the entire sample, we compare the robustness of theoretical and empirical mass-radius relationships.

Probing variability in young low-mass stars with TESS and high resolution spectroscopy

Gabriella Zsidi (1); Péter Ábrahám (2); Evelyne Alecian (3); Gaitee Hussain (4); Ágnes Kóspál (5); Carlo Manara (6); Attila Bódi (7); András Pál (8)

(1) European Southern Observatory & Konkoly Observatory; (2) Konkoly Observatory; (3) IPAG /CNRS/Univ. Grenoble Alpes; (4) European Southern Observatory; (5) Konkoly Observatory & Max Planck Institute for Astronomy; (6) European Southern Observatory; (7) Konkoly Observatory; (8) Konkoly Observatory

Young stellar objects are still surrounded by a circumstellar disk, from which material is falling onto the stellar surface. This mass accretion process is essential in the formation of Sun-like stars. Although usually described with simple and static models, the accretion process is inherently time variable. Here, we present the analysis of 6 low-mass young stellar objects located in the Chamaeleon I star forming region. The aim of our work is to characterize the geometry and variability of the accretion process by using several accretion tracers. In order to examine the accretion process in the time domain, we need multiple epochs of high cadence photometric data and high-resolution spectroscopic data. We present optical photometric observations obtained by the TESS space telescope, which provides uninterrupted light curves with 30 minutes cadence and high-resolution spectroscopic monitoring observations with the VLT/ESPRESSO and the 2.2m/FEROS spectrographs. Our extensive data set allows us to examine the amplitude, the timescale and the pattern of the flux changes, which carry information on the distribution and the kinematics of the accreting material, on the density structure of the inner disk and on the presence of outflows or jets. Where we have simultaneous photometry and spectroscopy we link the photometric variability to spectroscopic variations. For 2 systems we complemented our data with spectropolarimetric observations which allow us to examine the role that the large scale stellar magnetic field plays in the accretion process.

Search for wide substellar companions to Young Nearby Stars with VISTA Hemisphere Survey.

Patricia Chinchilla (1); Víctor J.S. Béjar (2); Nicolas Lodieu (3); Bartosz Gauza (4); Maria Rosa Zapatero Osorio (5); Antonio Pérez Garrido (6); Rafael Rebolo (7); Elena Manjavacas (8); Carlos Alvarez. (9)

(1) IAC & Universidad de La Laguna; (2) IAC & Universidad de La Laguna; (3) IAC & Universidad de La Laguna; (4) University of Zielona Góra; (5) Centro de Astrobiología (CSIC-INTA); (6) Universidad Politécnica de Catagena; (7) IAC & Universidad de La Laguna & CSIC; (8) W.M. Keck Observatory; (9) W.M. Keck Observatory.

We present our search for brown dwarfs and planets orbiting young nearby stars of the Upper Scorpius region and some known Young Moving Groups. Wide-orbit companions up to 50,000 AU were identified using proper motion measurements and color-magnitude diagrams obtained from near-infrared catalogs like VISTA Hemisphere Survey (VHS), UKIDSS Galactic Clusters Survey (GCS) and 2MASS. We also used Gaia DR2 astrometric data to discard casual alignments for the

brightest candidates. The true companionship of some candidates was spectroscopically confirmed with optical and/or near-infrared data, e.g. USco1621 B and USco1556 B, two wide companions at the deuterium-burning mass limit in Upper Scorpius. We report on the multiplicity frequency for low-mass wide binaries at young ages, very useful to compare with the predictions of the formation models.

The Extreme Ultraviolet Spectrum in Time: Modeling the Evolution of Early M dwarf Emission

Sarah Peacock (1); Travis Barman (2); Evgenya L. Shkolnik (3); R. O. Parke Loyd (4); Adam C. Schneider (5); Isabella Pagano (6); Victoria S. Meadows (7)

(1) University of Arizona, Lunar and Planetary Laboratory; (2) School of Earth and Space Exploration, Arizona State University; (3) INAF - Osservatorio Astrofisico di Catania; (4) Department of Astronomy and Astrobiology Program, University of Washington

The evolution of a host star's extreme ultraviolet (EUV, 10-100 nm) emission is crucial for understanding the evolution of planetary atmospheres and climates. Short wavelength radiation is absorbed in the upper atmospheric layers of close-in exoplanets, causing photochemical reactions, heating and expansion to occur. When exposed to large amounts of EUV radiation, planets are vulnerable to global-scale water loss and significant atmospheric escape. Previous results from the HAbitable Zones and M dwarf Activity across Time (HAZMAT) program have shown that both X-ray and far- and near-UV (FUV; NUV) emission emitted from M dwarfs is elevated for the first several hundred million years. During this period, planets are forming their atmospheres and both thermal and non-thermal atmospheric escape rates are at their highest. Unfortunately, observational limitations prevent access to EUV wavelengths, impeding the ability to directly measure EUV flux as a function of age. Here, we present recent results quantifying the lifetime evolution of stellar EUV radiation. Using the PHOENIX atmosphere code and empirical guidance from GALEX UV photometry, we compute high resolution synthetic spectra for early M dwarfs at five distinct ages between 10 Myr and 5 Gyr. We model a range of EUV fluxes spanning two orders of magnitude, consistent with the observed spread in X-ray, FUV, and NUV flux at each epoch. Our results show that the EUV emission from young M stars is 100 times stronger than from field age stars, and decreases as 1/t. Both the EUV-NUV continuum and individual line fluxes (e.g. H I Lyα, Mg II, N V) decrease most notably after 650 Myr, showing general consistency for the first few hundred million years of the stellar lifetime followed by a 1-2 order of magnitude decrease in flux. Our models reconstruct the full spectrally and temporally resolved history of an M star's UV radiation, including the unobservable EUV radiation that drives planetary atmospheric escape, directly impacting a planet's potential for habitability.

Near-Infrared Spectroscopic Monitoring of Low-Mass, Persistent Flux-Dipping Systems in Upper Sco

Benjamin Tofflemire (1); Adam Kraus (2); Aaron Rizzuto (3); Greg Mace (4)

(1) The University of Texas at Austin; (2) The University of Texas at Austin; (3) The University of Texas at Austin; (4) The University of Texas at Austin

In the era of space-based, time-series photometry (e.g., CoRoT, Kepler, TESS), stellar variability has provided an invaluable lens on the physics of stellar magnetism and the interaction between stars and their circumstellar environment. One of the more enigmatic classes of stellar variability to

emerge from the Kepler K2 mission are the "scallop-shell" or persistent flux-dipping systems. These stars exhibit narrow dimming events with variable morphologies and depths that are periodic with the stellar rotation. With more systems now being discovered with TESS, the growing sample are consistently young ($\sim$<100 Myr), low-mass M dwarfs with rapid rotation (P < 1 day). Without evidence for disk material or massive companions, three hypotheses have been put forth to explain these systems: 1) magnetically confined dust clouds orbiting at the co-rotation radius, 2) a short-period, enshrouded protoplanet, or 3) pathological spot variability. To illuminate the source of this variability, we have monitored 4 persistent flux-dipping systems in Upper Sco with high-resolution, near-infrared spectra from the IGRINS spectrograph (simultaneous H- and K-band coverage at R$\sim$45000). We find large rotational velocities consistent with near edge on orientations and no significant radial-velocity variability. Line profiles show evidence for large and evolving spot features, making these systems prime candidates for future doppler tomographic studies.

Fundamental properties for M-dwarfs in eclipsing binaries: the case for SB1 vs SB2 analyses

Yilen Gómez Maqueo Chew (1); Leslie Hebb (2); Elizabeth Moreno Hilario (3)

(1) Instituto de Astronomía UNAM; (2) Hobart and William Smith Colleges; (3) Instituto de Astronomía UNAM

In the last several years, eclipsing binary systems composed of a solar-type primary star and an M-dwarf secondary have been utilized to measure the properties of M-dwarf stars, includiing their metallicity. Typically, these FGK+M binaries, a by-product of the search for transiting planets, are single-lined spectroscopic binaries. Thus, the fundamental properties of both stars depend on the relatively well-understood evolutionary models for solar-type stars. Here we present our analysis for eclipsing binaries composed of a solar-type star and and M-dwarf using their Kepler light curve and APOGEE spectra. We are able to compare the fundamental properties of the M-dwarfs resulting of the analysis of the primary's radial velocity curve and of the analysis of both primary and secondary radial velocity curves. We find that in some cases the single-lined analysis has systematic uncertainties that may skew the M-dwarf results.

Biases Introduced in Observed IMFs by Undetected Binary Systems

Kendall Sullivan; Adam L. Kraus

University of Texas at Austin

The initial mass function (IMF) defines the mass distribution of a population of newly-formed stars, and is useful as a diagnostic of star formation physics. Most evidence indicates that the IMF is mostly universal, but some star forming regions, like Taurus, are discrepant with that universal IMF. One explanation for this discrepancy is multiplicity. Unresolved binary stars in variably extincted and spatially extended regions may not have the age or mass corresponding to their apparent position on an HR diagram. Binaries are often expensive or impossible to identify via observations (e.g., high-resolution imaging or spectroscopy) and thus are not easily screened from samples. In lieu of traditional observations, we have carried out a synthetic low-resolution optical spectroscopic survey of a young star-forming region, to investigate the effect of unresolved binary stars on derived population statistics, including the IMF. Our simulated population includes unresolved close binaries, and we determine each system's apparent effective temperature and luminosity using spectral fitting. Then, we use evolutionary models to infer an age and a mass for each system, allowing us

to explore the apparent age and mass distribution produced by a population including unresolved multiplicity. We will present the initial results of this synthetic study, including the potential biases that may have been introduced into the IMF by past surveys of young stellar populations.

A deep learning approach to photospheric parameters of CARMENES target stars

Vera Maria Passegger (1); Joaquín Ordieres-Meré (2); Antonio Bello-García (3); José Antonio Caballero for the CARMENES Consortium (4)

(1) Hamburger Sternwarte, Gojenbergsweg 112, D-21029 Hamburg, Germany; (2) Homer L. Dodge Department of Physics and Astronomy, University of Oklahoma, 440 West Brooks Street, Norman, OK 73019, United States of America; (3) Departamento de Ingeniería de Organización, Administración de Empresas y Estadística, Universidad politécnica de Madrid, C/José Gutiérrez Abascal 2, E-28006 Madrid, Spain; (4) Departamento de Construcción e Ingeniería de Fabricación, Universidad de Oviedo, c/Pedro Puig Adam, Sede DepartamentalOeste, Módulo 7, 1a planta, E-33203 Gijón, Spain; (5) Centro de Astrobiología (CSIC-INTA), ESAC, Camino Bajo del Castillo s/n, E-28692 Villanueva de la Cañada, Madrid, Spain

In the light of more and more new instrumentations to get a deeper insight into the universe, tons of data are collected. While traditional machine-learning methods have been used in processing stellar spectral data, such large new datasets are better dealt with Deep Learning (DL) techniques. In this work, we present a Deep Convolutional Neural Network (CNN) approach to derive fundamental stellar parameters (effective temperature, surface gravity, metallicity and rotational velocity) from high-resolution high signal-to-noise ratio spectra. We construct an individual CNN architecture for each of the four parameters and train them on synthetic PHOENIX-ACES spectra. After that, we apply the trained networks to the observed spectra of 50 M dwarfs observed with CARMENES. The CARMENES spectrograph, installed on the 3.5 m telescope at the Calar Alto Observatory (Spain) has two channels, covering the visible (0.52 to 0.96 µm, R = 96,400) and near-infrared (0.96 to 1.71 µm, R = 80,600) spectral ranges. We compare our results to literature values, and demonstrate that our method can be used for stellar parameter determination without the need of having a huge sample of stellar spectra with known parameters, because our networks can be trained on synthetic models.

The young nearby quadruple system HD98800: Refining the orbit of HD98800 BaBb and first orbital solution for HD98800 AaAb using long baseline infrared interferometry

S. Zúñiga-Fernández (1); J. Olofsson (2); G. Kennedy (3); X. Haubois (4); A. Gallenne (5); A. Bayo (6); J. P. Berger (7); J. M. Corral-Santana (8)

(1) Núcleo Milenio de Formación Planetaria (NPF), Valparaíso, Chile; (2) European Southern Observatory, Vitacura, Santiago de Chile, Chile; (3) Universidad de Valparaíso, Instituto de Física y Astronomía (IFA), Valparaíso, Chile; (4) Department of Physics, University of Warwick, Coventry, UK; (5) Université Grenoble Alpes, CNRS, IPAG, Grenoble, France

HD 98800 is a young (∼10 Myr old) and nearby (44.9 pc) quadruple system, composed of two spectroscopic binaries orbiting around each other (AaAb and BaBb). The BaBb component harbours a proto-planetary disk that has very recently been spatially resolved with ALMA (Kennedy et al. 2019). The AB and BaBb components have orbital solutions in the literature, and the ALMA

observations revealed that the disk is in a polar configuration with respect to the BaBb orbital plane. In our effort towards obtaining a full characterization of the HD 98800 binary components, we have been awarded with time in the NAOMI+PIONIER science verification (SV) to verify the viability of the BaBb orbital solution and obtain a first point for the AaAb orbit. Also we were awarded with P104 and P105 PIONIER observation time for the AaAb subsystem for monthly measurements (Dec 2019 - June 2020). The preliminary results will be presented, including the first orbital solution for the AaAb subsystem and the implication on the dynamics of the BaBb binary system with respect to the circumbinary disc will be discussed.

Near infrared polarimeteric study of post-AGB stars

Devaraj Rangaswamy (1); Abraham Luna (2); Julio Ramirez Velez (3); Laurence Sabin (4); Tom Ray (5)

(1) Dublin Institute for Advanced Studies (DIAS); (2) Instituto Nacional de Astrofisica, Optica y Electronica (INAOE); (3) Universidad Nacional Autónoma de México (UNAM); (4) UNAM; (5) DIAS

Post-Asymptotic Giant Branch (AGB) stars show complex morphologies with a dusty circumstellar envelope due to mass ejected during AGB phase. In this work, we present near-infrared polarimetric study for a sample of 7 post-AGB stars exhibiting large color excess. Observations in J, H and K bands were carried out using POLICAN instrument on the 2.1m OAGH telescope at Cananea, Mexico. Results show the stars have a degree of polarization ranging from 2 to 10%. On average, the stars display a wavelength-dependent of polarization that increases towards shorter wavelength, implying an intrinsic origin of the polarization. The polarization origin is due to Rayleigh-like scattering mechanism by small dust grains in the dusty envelopes. We also find evidence of multiple scattering in the outflows for the stars with bipolar envelopes.

SED fitting for pre-MS stars: Applications for an Age Spread and Starspots in Young Clusters

Lyra Cao (1); Marc H. Pinsonneault (2); Lynne A. Hillenbrand (3); Michael A. Kuhn (4)

(1) The Ohio State University; (2) The Ohio State University; (3) California Institute of Technology; (4) California Institute of Technology

We use spectral energy distribution (SED) fitting techniques to infer the dispersion in age of pre-MS stars in star forming regions. This SED fitting scheme uses a suite of empirical and calibrated theoretical colors that are tested on the open clusters Pleiades and Praesepe and are consistent for obtaining stellar parameters from individual young stars. We apply this suite to λ Orionis and show that there is a physically-motivated variation in extinction between our stars, and discuss the presence of an age spread of cluster members. We augment this suite of tools with an additional starspot parameter with a reverse-modelling exercise and show that it is possible to do a self-consistent test with two-temperature starspot evolutionary tracks and starspot-perturbed evolutionary tables to measure activity in h & χ Persei.

Measuring Differential Rotation with Stellar Surface Images

Rachael M. Roettenbacher (1); John D. Monnier (2); Robert O. Harmon (3)

(1) Yale University; (2) University of Michigan; (3) Ohio Wesleyan University

Starspots on cool, active stars can form at different stellar latitudes. As a result, the starspots will indicate slightly different stellar rotation rates due to differential rotation. Differential rotation has been observed spectroscopically and photometrically on a number of stars. To measure differential rotation parameters of spotted stars with photometry in an analogous way to spectroscopic efforts, we use light-curve inversion and reconstruct spotted stellar surfaces using Kepler light curves. We cross-correlate sequential surfaces (rotations) and measure the amount of differential rotation. Here, we share details of our method and our results. Additionally, we will put this method and its results in context with our study of stellar activity in the Kepler archive.

Spectroscopic information contained in the CARMENES VIS and NIR spectral ranges of FGKM stars

David Montes (1); Fernando Labarga (2); Álvaro López-Gallifa (3); Emilio Marfil (4); CARMENES consortium (5)

(1) Depto. de Física de la Tierra y Astrofísica, Universidad Complutense de Madrid, UCM & IPARCOS-UCM; (2) CARMENES

In this contribution we summarize the different spectroscopic information that can be extracted from visible and near-infrared CARMENES spectra of FGKM stars. 1) Fundamental stellar parameters ($T_{\rm eff}$, $\log g$, [Fe/H]) from individual spectral lines (EW method) and from spectral synthesis, identifying iron and titanium line lists and molecular bands from different types of stars (temperature, luminosity class and metallicity) that are more suitable for these two methods. 2) A line list compilation to be used to derive chemical abundances in these stars. 3) Quantify the chromospheric activity level with well known activity indicators (NaI D1, D2 HeI D3, H_α and CaII IRT lines, HeI 10830 AA, Pγ and Pβ lines) using the spectral subtraction technique and analysis of the flux-flux relations. 4) Identification of other chromospheric activity-sensitive spectral lines in particular during strong flares. 5) Identification of magnetically sensitive lines (Zeeman broadening) specially in the NIR were the Zeeman effect is larger. 6) Study the influence of lines identified in point 4) and 5) in the spectral region used to derive radial velocities and help to solve the problem of stellar activity in radial velocity measurements to search for exoplanet around these stars.

Effects of Extra Mixing in Red Giant Branch Stars in M10

Jeffrey M. Gerber (1); Zachary G. Maas (2)

(1) Max Planck Institute for Astronomy & Indiana University; (2) University of Texas at Austin & Indiana University

Non-canonical extra-mixing is important in low-mass, red giant branch (RGB) stars that have passed the evolutionary phase of the luminosity function bump. While the effects of this extra mixing are established through abundance measurements in RGB stars, there is not a theory of non-canonical extra-mixing that can accurately predict the observations. Stars undergoing this extra-mixing are observed to have surface abundances that are consistent with CN(O)-cycle material; therefore, the extra-mixing must bring processed material from the H-burning layer to the stellar atmosphere through the convective envelope.

To further explore non-canonical extra mixing, we measured the $^{12}\mathrm{C}/^{13}\mathrm{C}$ ratio in 31 RGB stars in the globular cluster M10 over a range of –2.33 < M_V < 0.18. We compared the $^{12}\mathrm{C}/^{13}\mathrm{C}$ ratio between both stellar populations in M10 and found an average $^{12}\mathrm{C}/^{13}\mathrm{C}$ of 4.84 for the second generation (CN-enhanced population) and 5.10 for the first generation (CN-normal population). We then used $^{12}\mathrm{C}/^{13}\mathrm{C}$, [C/Fe], and [N/Fe] ratios in M10 to constrain theoretical models created with MESA that use thermohaline mixing as the non-canonical mixing source. Based on these comparisons, we show how current models cannot explain both the carbon depletion and the $^{12}\mathrm{C}/^{13}\mathrm{C}$ decrease with a single thermohaline efficiency parameter. Finally, we compared these models to our preliminary measurements of lithium in the cluster.

Probing the Low-Mass End of the Initial Mass Function with an HST DASH Survey of Massive Star-Forming Regions

William M. J. Best (1); Adam L. Kraus (2); Katelyn N. Allers (3); Beth Biller (4); Brendan P. Bowler (5); Trent J. Dupuy (6); Clemence Fontanive (7); Kaitlin Kratter (8); Jessica Lu (9); Stella Offner (10); Megan Reiter (11); Aaron Rizzuto (12)

(1) University of Texas at Austin; (2) University of Texas at Austin; (3) Bucknell University; (4) University of Edinburgh; (5) University of Texas at Austin; (6) Gemini Observatory; (7) University of Bern; (8) University of Arizona; (9) University of California - Berkeley; (10) University of Texas at Austin; (11) University of Edinburgh; (12) University of Texas at Austin

As the lowest-mass objects created by star formation processes, brown dwarfs are essential to a complete understanding of star formation in our galaxy. Leading models of the Initial Mass Function (IMF) differ most dramatically at the extreme low-mass tail, making brown dwarfs and free-floating planets the most sensitive test population for identifying the IMF's shape and possible variations. However, the low-mass IMF remains poorly constrained due to meager samples of these faint objects in the Solar neighborhood and nearby, relatively small star-forming regions. We are using deep HST drift-and-shift (DASH) images of five massive benchmark Milky Way star-forming regions beyond the Solar neighborhood to comprehensively identify members down to planetary masses and explore variations of the IMF with star-forming environment. We are leveraging 1.4-micron water band photometry to distinguish reddened field interlopers from low-temperature cluster members and quantify interstellar extinction, an approach that is difficult to replicate from the ground. We present initial results from our survey, including a method to calibrate the relative contributions of extinction and water absorption using foreground stars identified by Gaia DR2 parallaxes.

Explosive nucleosynthesis as the source of a distinct odd-even effect in the solar twin HIP 11915

Jhon Yana Galarza (1); Jorge Meléndez (2); Diego Lorenzo-Oliveira (3); Amanda I. Karakas (4); Martin Asplund (5); Lorenzo Spina (6); Fan Liu (7)

(1) Universidade de São Paulo; (2) Universidade de São Paulo; (3) Universidade de São Paulo; (4) Monash University; (5) The Australian National University; (6) Monash Universit; (7) Lund University

The odd-even effect is clearly observed in the Sun and metal-poor stars. An important question is whether the odd-even effect in solar-metallicity stars is similar to the Sun, or if there are variations that can tell us about different enrichment histories by supernova. In this work, we report for the first time evidence of the odd-even effect in the solar twin HIP 11915. The spectra of this star were obtained with high resolving power (140 000) and signal-to-noise ratio (~420) using the ESPRESSO spectrograph and the VLT telescope. Thanks to this precision, we obtained extremely precise stellar parameters ($\sigma(T_{\rm eff})$ = 4 K, $\sigma([\mathrm{Fe/H}])$ = 0.005 dex, and $\sigma(\log g)$ = 0.008 dex). We also determined the abundance of 18 light elements ($Z \leq 30$), which shows a clear pattern of the odd-even effect, whose

dispersion is much bigger than their abundance uncertainties (∼0.01 dex). Our results indicate that HIP11915 has an odd-even effect somewhat different than the Sun, pointing out for a somewhat different supernova enrichment history.

Unveiling Brown Dwarf and White Dwarf Binary Candidates in the Solar Neighborhood

Wei-Chun Jao (1); Serge Dieterich (2); Todd Henry (3)

(1) Georgia State University; (2) STScI, RECONS Institute

By searching the hidden gems in the Gaia DR2, we have identified possible new brown dwarf and white dwarf (WD+BD) binary candidates in the solar neighborhood. Finding such rare WD+BD pairs are uniquely important in the study of substellar structure and evolution, especially understanding the brown dwarf cooling rates. In this work, we present how these candidates are identified in the DR2 and their impacts of understanding brown dwarfs.

The limb darkening on the detection of exoplanets and exomoons

Gabriel Zuza Diniz; Eduardo Nunes Velloso; Leandro de Almeida; José Dias do Nascimento Júnior

UFRN, Federal University of Rio Grande do Norte, Natal, RN, Brazil

Stellar limb darkening is an important parameter in the analysis of transits light curves, whether from systems consisting of binary stars, planets or even moons. The depth of the transit on the light curve is primarily determined by the ratio of the radius of the second body to the radius of the star. By modeling the planetary transit, we can retrieve information about the limb darkening coefficients and better understand the brightness profile of the star. The general effect of limb darkening is the change in the depth of the light curve as a function of the impact parameter and profile modification of the transit. In this work, we present simulations with different limb darkening law prescriptions and corresponding consequences for detecting transit events. For this purpose, we simulate various systems with the main predefined parameters, such as radius fraction, major half axis, orbital period, inclination, eccentricity, and limb darkening coefficients of various laws, and apply the noise and systematic errors of various space missions (Kepler, TESS and PLATO). The idea is to recover the signal of the original simulated light curve in a blind procedure.

Exploring the Rotational Evolution of M Dwarfs

Mark Popinchalk (1); Jacqueline Faherty (2); Kelle Cruz (3); Rocio Kiman (4); Emily Rice (5); Jason Curtis (6); Ruth Angus (7)

(1) CUNY Graduate Center; (2) Hunter College; (3) American Museum of Natural History; (4) Macaulay Honors College; (5) Flatiron Institute

A star's age and its rotation rate are linked. Stars tend to rapidly rotate while young, and as they age they lose angular momentum and spin down, likely due to interactions with their magnetic fields. The time scale for spin down is expected to be dependent on stellar mass, and this rotation-age relationship has not been precisely calibrated for M dwarfs.

Dark spots that form on the photosphere of a star will rotate along with the surface. This can be detected as periodic photometric variability in time series data, from which we can measure the rotation rate of the star. In this poster we will present measurements of the rotation periods for a sample of over 1,000 M dwarfs observed in the Kepler K2 survey.

Additionally, we have attempted to compile every known M dwarf rotation rate from published catalogs. These include young open clusters of known ages such as the Hyades, Pleiades, Praesepe, and Rho Ophicius, as well as field samples of unknown ages. We use Gaia photometry to consider samples together, and when possible we include additional age diagnostics such as kinematics and H-alpha activity. From this we provide context for the age estimates of our sample and discuss the greater M dwarf gyrochronology landscape.

CESTAM: Toward a stellar evolution code with angular momentum transport in 2 dimensions

Louis Manchon; João P. C. Marques

Institut d'Astrophysique Spatiale, Université Paris-Saclay, Orsay, France

Stellar rotation evolution is often modeled assuming that the rotation rate is constant in a spheroidal shell, the so-called *shellular rotation*, which allows a simple one dimensional treatment. However, angular velocities predicted by these models are not consistent with observations by CoRoT, *Kepler* and TESS. For instance, the cores of red giants rotate with rotation rates two orders of magnitude smaller than predicted by these models. This suggests that additional mechanisms of transport of angular momentum are needed such as gravity modes or magnetic instabilities. In the case of angular momentum transport by gravity waves, the quantity of angular momentum carried by the wave depends on the Doppler effect between the zone where it is emitted and the zone where it is dissipated. Since the rotation rate can vary in latitude, only a 2D treatment of rotation can fully apprehend such mechanism. We aim at studying the validity of the hypotheses on which shellular angular momentum transport is built upon. To that end we improved the stellar evolutionary code CESTAM so that, during the computation of each time step, the transport of angular momentum in the radiative zone is computed in 2D. This allow us to obtain an averaged the 1D mode which, at the end is deformed and 2D quantities can be computed, and used for the next time step. The modeling is based on the formalism of Roxburgh (2006) for the 2D stellar structure and on the one of Mathis & Zahn (2004) for the transport of angular momentum. Those formalisms are both based on the projection of solutions on Legendre polynomials. From a purely computation efficiency point of view, our code is almost as fast as the 1D version of CESTAM. The deformed 2D models can be coupled with a 2D oscillation code such as the ACOR code, without assuming an ad hoc rotation profile. It has already been used to study oscillations and improve our understanding of fast rotators such as δScuti.

Investigating the Galactic Distribution of UCDs in Deep Fields

Christian Aganze; Adam Burgasser

University of California, San Diego

Ultracool dwarfs (UCDs, M<0.1 Msun, Teff <3000K) are the lowest-mass objects in the Milky Way and members. Like stars, they are tracers of Galactic structure and star-formation history, while the cooling of substellar UCDs provide additional probes for galactic archeology and chemical evolution. Wide-field optical and infrared surveys have provided samples up to distances < 100 pc. To push to larger distances, we have searched over 0.5 square degrees of the WFC3 Infrared Spectroscopic Parallel Survey (WISPS) and the 3D-HST parallel survey with low-resolution near-infrared spectra. We report the discovery of 180 M7-T9 and T dwarfs with spectro-photometric distances up to $\sim$2 kpc for L dwarfs and $\sim$400 pc for T dwarfs. We model the number density distribution with population simulations incorporating various assumptions of the intrinsic MF and birth rates, binary fraction, and accounting for UCD evolutionary models and Galactic structure. We find the number density of scale height of L dwarfs to be 200–300 pc while the T dwarf scale height is 400 pc. Using separate measurements from the velocity dispersions in the local neighborhood by Hsu et. al. 2020, we use a hierarchical bayesian model to put constraints on the scale heights and the power-law index of the sub-stellar initial mass function.

The chromospheric activity of solar-like stars revisited

Rafael Ferreira; Matthieu Castro; José Dias do Nascimento Jr.

Universidade Federal do Rio Grande do Norte, Brazil

The evolution of solar and stellar magnetic activity has been subject to intense investigations along the last decades. Searching to characterize the magnetic activity behavior of solar-type stars in time, several surveys have been performed over the last 60 years. We are revisiting and enhancing the chromospheric activity determination of approximately 4500 solar-like stars originally inferred by the Mount Wilson project. In addition, we are computing the activity indexes (Ca II H&K, Ca IRT and Hα index) from HARPS, NARVAL, ESPADONS, ELODIE and SOPHIE high-resolution spectra archive available. It allows us to cover a larger time interval over 60 years. We are determining the activity-cycle periods using the Lomb-Scargle periodogram to analyze the active and inactive branches in the rotation-activity-cycle diagram. We are also looking for stars with flat activity in this sample, as the way to find Maunder minimum stars.

Probing the Radius-Magnetic Activity Connection for M0 to L2.5 Dwarfs

Michele L. Silverstein (1); Todd J. Henry (2); Serge B. Dieterich (3); Joshua E. Schlieder (4); Thomas Barclay (5); Emily A. Gilbert (6); Wei-Chun Jao (7); Teresa A. Monsue (8); Rishi R. Paudel (9); Adric R. Riedel (10); Kenneth J. Slatten (11); Laura D. Vega (12); Jennifer G. Winters (13); Allison Youngblood (14)

(1) NASA Goddard Space Flight Center & RECONS Institute; (2) RECONS Institute; (3) Space Telescope Science Institute; (4) NASA Goddard Space Flight Center; (5) NASA Goddard Space Flight Center & University of Maryland, Baltimore County; (6) University of Chicago & NASA Goddard Space Flight Center; (7) Georgia State University; (8) NASA Goddard Space Flight Center; (9) NASA Goddard Space Flight Center & University of Maryland, Baltimore County; (10) Space Telescope Science Institute; (11) RECONS Institute; (12) NASA Goddard Space Flight Center & Vanderbilt University; (13) Center for Astrophysics | Harvard and Smithsonian; (14) Laboratory for Atmospheric and Space Physics

Low-mass star radii provide a gold mine of information. Age, metallicity, and magnetic activity all affect stellar radii. Young stars have inflated radii compared to main sequence stars, while cool subdwarfs are more compact. In addition, transiting exoplanet characterization is at the mercy of accurate stellar parameters. All of these lines of inquiry deserve focused attention with the goal of providing carefully derived radii. To this end, we present the latest results of the Systematic Investigation of Radii and Environments of Nearby Stars (SIRENS) project. Using a uniform methodology,

we derive effective temperatures and radii for our 25 parsec, volume-limited, all-sky sample of 1500 stars that spans an unparalleled spectral type range of M0 to the end of the stellar main sequence at L2.5. Our method utilizes optical to mid-IR photometry, a large wavelength coverage encompassing 95% to 99.9% of the stellar flux emitted by these stars. Our stellar radii match those derived via long-baseline interferometry to ∼6%, supporting the reliability of the method. By characterizing a statistical sample across an unprecedented mass range, we reveal new trends in the effective temperature-radius relation of M0 to L2.5 dwarfs. Here we explore those trends, with an emphasis on their connection to starspots and flares.

Dynamical Masses of Young Stars

Aaron C. Rizzuto (1); Adam L. Kraus (2); Michael J. Ireland (3); Trent Dupuy (4)

(1) University of Texas at Austin; (2) Australian National University; (3) Gemini Observatory

Stellar evolutionary models underlie vast tracts of modern astrophysics, from the IMF to exoplanets, and yet models are still largely uncalibrated at pre-main sequence ages. This shortfall results from the distance to star-forming regions, which makes it difficult to measure dynamical masses for binary pairs; until recently, even the tightest visual binaries had orbital periods of many decades. We have used nonredundant aperture-mask interferometry (which attains resolutions 3-4 times higher than normal imaging) to monitor a sample of 30 young binary systems in Taurus (1-5 Myr), Ophiuchus (1-3 Myr), and the Sco-Cen (10-20 Myr) association. We present the current sample of 1-3% dynamical masses for 10 Taurus and Sco-Cen binaries with ages <15 Myr, and in combination with spectral and SED information show that model ages for coeval stars differ by up to a factor of two as a function of stellar effective temperature. In particular, physically associated and likely coeval neighbour stars known to be single appear to be older (∼5-6 Myr) according to the same models. This discrepancy in age is equivalent to a luminosity under-prediction of 0.1-0.2 dex, or a temperature over-prediction of 100-300 K for K/M-type stars at a given model age. We interpret this as further evidence for a discrepancy in the current generation of pre-main sequence evolutionary tracks for convective stars, as seen in visual and eclipsing binary systems in the 10 Myr Upper Scorpius OB association. We suggest that the classical Taurus population has a mean age of ∼5 Myr and that star-formation in Taurus has been ongoing for at least the past 5 Myr. Given that many populations of young stars in star-forming regions are age-dated on the basis of low-mass member HR-diagram positions, we suggest that stellar ages may require upward revision even for the youngest (0-5 Myr) populations.

Investigating the Galactic Distribution of UCDs in Deep Fields

Christian Aganze; Adam Burgasser

UC San Diego

Ultracool dwarfs (UCDs, M<0.1 Msun, Teff <3000K) are the lowest-mass objects in the Milky Way and members. Like stars, they are tracers of Galactic structure and star-formation history, while the cooling of substellar UCDs provide additional probes for galactic archeology and chemical evolution. Wide-field optical and infrared surveys have provided samples up to distances < 100 pc. To push to larger distances, we have searched over 0.5 square degrees of the WFC3 Infrared Spectroscopic Parallel Survey (WISPS) and the 3D-HST parallel survey with low-resolution near-infrared spectra. We report the discovery of 180 M7-T9 and T dwarfs with spectro-photometric distances up to ∼2 kpc for L dwarfs and ∼400 pc for T dwarfs. We model the number density distribution with population simulations incorporating various assumptions of the intrinsic MF and birth rates, binary fraction, and accounting for UCD evolutionary models and Galactic structure. We find the number density of

scale height of L dwarfs to be 200–300 pc while the T dwarf scale height is 400 pc. Using separate measurements from the velocity dispersions in the local neighborhood by Hsu et. al. 2020, we use a hierarchical bayesian model to put constraints on the scale heights and the power-law index of the sub-stellar initial mass function.

Optical Spectroscopy of New Nearby Ultracool Dwarfs from Gaia DR2 and SDSS-LaTE-MoVeRS

Adam Burgasser (1); Celine Reyle (2); Christopher Theissen (3); Ryan Low (4); Roman Gerasimov (5); Dino Hsu (6); Christian Aganze (7); Niana Mohammed (8); Richard Smart (9); Kelle Cruz (10)

(1) UC San Diego; (2) Observatoire de Besançon; (3) UC San Diego; (4) UC San Diego; (5) UC San Diego; (6) UC San Diego; (7) UC San Diego; (8) UC San Diego; (9) INAF Osservatorio Astrofisico di Torino; (10) CUNY Hunter College/American Museum of Natural History

Astrometric selection of the nearest stars, via proper motion or parallax, continue to uncover previously unidentified, low-mass stellar systems in the Solar Neighborhood, ideal targets for planet detection studies. Here we report on optical spectroscopic follow-up of over 100 ultracool dwarf candidates identified as high proper motion red sources in SDSS (LaTE-MoVeRS; Theissen et al. 2017); and large parallax, faint red sources in Gaia DR2 (Reyle 2018). Many of these sources - primarily late-type M dwarfs - have no reported classifications in the literature, despite being $\lesssim$30 pc from the Sun. We report the distribution of spectral types, magnetic emission, and metallicity/surface gravity indices; and highlight several outstanding sources, including a previously overlooked K7+M6 wide pair at 14 pc, a very misclassified nearby ultracool dwarf (M2 -> M7), and several high velocity mild subdwarfs in the Solar Neighborhood.

Sub-subgiant Starspot Analysis Through Spectral Decomposition

Natalie M. Gosnell (1); Michael A. Gully-Santiago (2); Emily M. Leiner (3)

(1) Colorado College; (2) University of Texas at Austin; (3) Northwestern University/CIERA

Sub-subgiant stars lie below the subgiant branch on a cluster optical color-magnitude diagram (CMD), but are too red to be main sequence stars. Almost all sub-subgiant stars are single-lined spectroscopic binaries with short orbital periods of a few days with moderate X-ray luminosities. The presence of sub-subgiants cannot be explained with typical single-star stellar evolutionary pathways. One possible formation scenario for sub-subgiants is reduced luminosity as a result of inhibited convection due to the presence of strong magnetic fields. To better understand these physical mechanisms we focus on a single sub-subgiant system, S1063 in the open cluster M67. We present a spectral decomposition of a high-resolution IGRINS spectrum, providing constraints of the spot filling factor and spot and ambient photosphere temperatures. We place the spot filling factor into context of the optical variability of the star over four years, combining ground-based ASAS-SN data and three campaigns of K2 light curves. Although we focus on a single object here, these techniques would be useful for many spotted stars with both spectra and light curve information.

Rotation of solar analogs from the Kepler - Gaia cross-matching sample

J.-D. do Nascimento, Jr.; L. de Almeida; E. N. Velloso; F. Anthony; S. A.Barnes; S.H. Saar;

S. Meibom; J.S. da Costa; M. Castro; J. Y. Galarza; D. Lorenzo-Oliveira; J. Melendez; P. G. Beck

Universidade Federal do Rio Grande do Norte (UFRN), Physics Department, Natal, RN, Brazil & Harvard-Smithsonian Center for Astrophysics, 60 Garden St., Cambridge, USA

A issue to interpret the rotation period distribution for main-sequence stars by using Kepler mission data has been the lack of precise evolutionary status for these objects. We present here evolutionary status based on Gaia Data Release 2 parallaxes and photometry for more than 30,000 Kepler stars with rotational period measurements. We report new rotation periods for 125 solar analogs from the Kepler survey also analyzed in terms of effective temperature and evolutionary state. Our results show possible selection effects carried from previous rotation period surveys, resulting in a lack of old stars like the Sun. This new sample of solar analogs will contribute as a benchmark sample for future spaceborne missions like the PLAnetary Transits and Oscillations of stars (PLATO) mission under development by the European Space Agency.

Life on a Pale Red Dot

Elena González Egea; Joanna Ramasawmy; Maksym Lisogorskyi

University of Hertfordshire

What could other worlds look like? Exoplanetology is rapidly progressing, but the conditions on the surface of planets around cool stars are still left somewhat to our imagination. M dwarfs emit most of their light in the infrared, and if life could develop on planets around them, it would evolve very differently to the life we are familiar with on Earth. This photography project is a meeting of art and science, and engages with the principles of both disciplines to highlight the creativity and imagination inherent in scientific research.

We imagine humans venturing to a rocky planet around an M dwarf in the distant future. In this setting, we can explore everything from well understood scientific principles to the most cutting-edge speculative research – ranging from the physics of light and stars, to imagining the kinds of life one would find on such planets. Portraying a hopeful future of humanity overcoming global issues such as the climate emergency that we face today, we will draw attention to the value of our planet Earth and our role as humans.

We explore these ideas using Kodak Aerochrome, a false-colour infrared film developed for aerial photography. It makes green foliage look red, as chlorophyll reflects strongly in the infrared. This is an unique film that was discontinued in 2011 and will run out very soon, so this project will use some of the last rolls available.

Small-scale magnetism of main-sequence stellar atmospheres

Oskar Steiner (1); René Salhab (2); Svetlana V. Berdyugina (3); Bernd Freytag (4); Paul Rajaguru (5); Matthias Steffen (6)

(1) Leibniz-Institut für Sonnenphysik (KIS) and Istituto Ricerche Solari Locarno (IRSOL); (2) Leibniz-Institut für Sonnenphysik (KIS); (3) Leibniz-Institut für Sonnenphysik (KIS); (4) Department of Physics and Astronomy, Uppsala University; (5) Indian Institute of Astrophysics, Bangalore; (6) Leibniz-Institut für Astrophysik (AIP)

Three-dimensional radiation magnetohydrodynamic simulations of main-sequence stellar atmospheres were carried out in order to investigate structure and global consequences of the small-scale magnetism in these atmospheres. To this aim, the simulations start with either, a homogeneous vertical

magnetic field of 50 G or 100 G field strength, or, for comparison, without a magnetic field. These two settings are thought to represent states of high and low small-scale magnetic activity corresponding to maximum and minimum of a stellar magnetic cycle. It is found that the presence of small-scale magnetism increases the bolometric intensity and flux from the stellar surface in all investigated models. The surplus in radiative flux of the magnetic over the magnetic field-free atmosphere turns out to be most pronounced for early G-type stars. The strength of the magnetic field concentrations on the surface of optical depth unity stays remarkably unchanged at approximately 1700 G throughout the considered range of spectral types but the degree of rarefaction of the magnetic flux concentrations monotonically increases with effective temperature and so does their depression at the visible optical surface (Wilson depression). We also look at the limb darkening function of the various models.

Radial Velocity Photon Limits for the Dwarf Stars of Spectral Classes F-M

Ansgar Reiners; Mathias Zechmeister

Institut für Astrophysik Göttingen

The determination of extrasolar planet masses with the radial velocity (RV) technique requires spectroscopic Doppler information from the planet's host star, which varies with stellar brightness and temperature. We analyze Doppler information in spectra of F-M dwarfs utilizing empirical information from HARPS and CARMENES, and from model spectra. We come to the conclusions that an optical setup (BVR-bands) is more efficient that a near-infrared one ($YJHK$) in dwarf stars hotter than 3200 K. We publish a catalogue of 46,480 well-studied F-M dwarfs in the solar neighborhood and compare their distribution to more than one million stars from Gaia DR2. For all stars, we estimate the RV photon noise achievable in typical observations assuming no activity jitter and slow rotation. We find that with an ESPRESSO-like instrument at an 8m-telescope, a photon noise limit of 10 cm s^{-1} or lower can be reached in more than 280 stars in a 5 minute observation. At 4m-telescopes, a photon noise limit of 1 m s^{-1} can be reached in a 10 minute exposure in ≈10,000 predominantly sun-like stars with a HARPS-like (optical) instrument. The same applies to ∼3000 stars for a red-optical setup covering the RIz-bands, and to ∼700 stars for a near-infrared instrument. For the latter two, many of the targets are nearby M dwarfs. Finally, we identify targets in which Earth-mass planets within the liquid water habitable zone can cause RV amplitudes comparable to the RV photon noise. Assuming the same exposure times, we find that an ESPRESSO-like instrument can reach this limit for 1 $M_\oplus$ planets in more than 1000 stars. The optical, red-optical, and near-infrared configurations reach the limit for 2 $M_\oplus$ planets in approximately 500, 700, and 200 stars, respectively.

Authors index

N

O

P