22nd Cambridge Workshop on Cool Stars, Stellar Systems and the Sun

San Diego, CA, USA
24-28 June 2024

Abstracts of Talks and Posters

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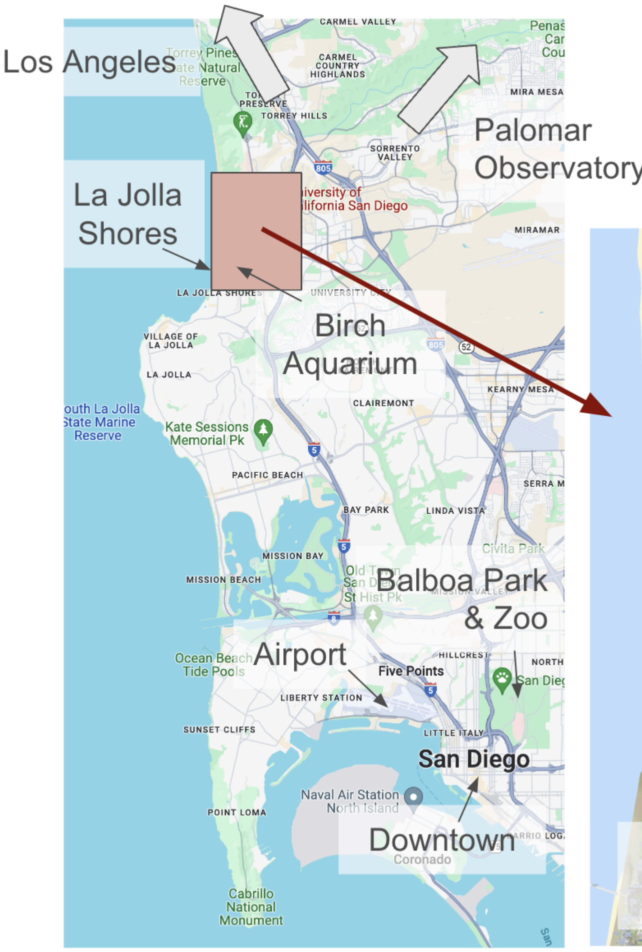
Maps and Emergency Contact Information



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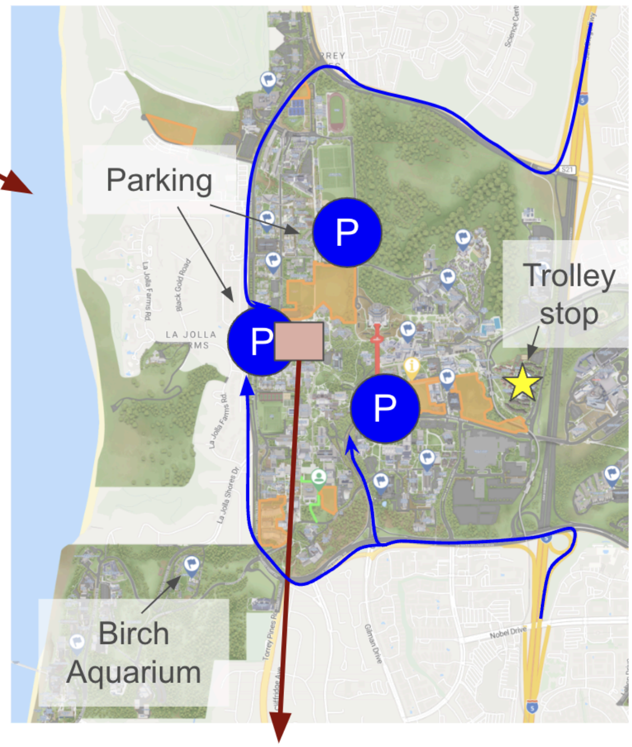
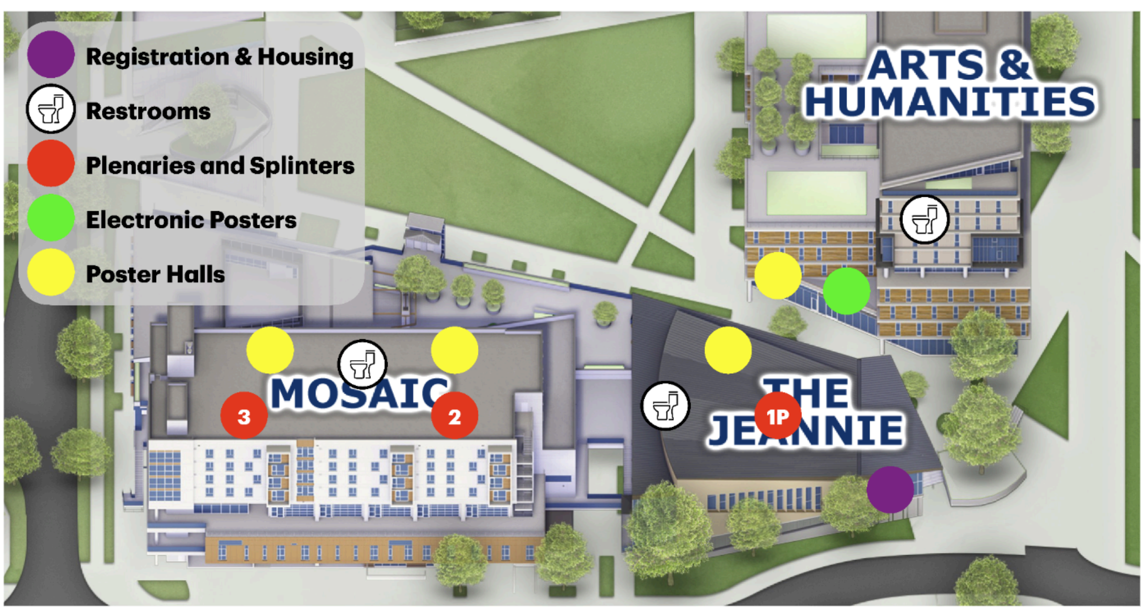
Campus Police: 858 534 4357
Medical emergencies: 911





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Conference Schedule

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Code of Conduct

The Cool Stars 22 organizers are committed to making this meeting productive and enjoyable for everyone, regardless of gender, sexual orientation, disability, physical appearance, body size, ethnicity, nationality, or religion. We will not tolerate harassment of participants in any form. Please follow these guidelines:

- Behave professionally. Harassment and sexist, racist, or exclusionary comments or jokes are not appropriate. Harassment includes sustained disruption of talks or other events, inappropriate or unwelcome physical contact, sexual attention or innuendo, deliberate intimidation, stalking, and photography or recording of an individual without consent. It also includes offensive comments related to gender, sexual orientation, age, disability, physical appearance, body size, ethnicity, or religion.
- All communication should be appropriate for a professional audience of people from many different backgrounds. Sexual language and imagery is not appropriate.
- Be kind to others. Do not insult or put down other attendees.
- Participants asked to stop any inappropriate behavior are expected to comply immediately. Attendees violating these rules may be asked to leave the event at the sole discretion of the organizers without a refund of any charge.

Any participant who wishes to report a violation of this policy can do so anonymously via google web form at https://bit.ly/4be5EX2 or can contact LOC representatives Preethi Karpoor or Chris Theissen.

Splinter Schedule

Monday

Learning from the Coldest Worlds in the era of JWST
Jackie Faherty (AMNH) and Aaron Meisner (NSF NOIRLab)

The Creation and Destruction of Lithium in Cool Stars
Julio Chanamé (Pontificia Universidad Católica de Chile); Robin Jeffries (Keele University); Sarah Martell (University of South Wales); and Marc Pinsonneault (The Ohio State University)

Unraveling the Magnetic Fields of (Sub)-Stellar Systems
Robert Kavanagh (ASTRON); John Sebastian Pineda (University of Colorado Boulder); & Mary Knapp (MIT Haystack Observatory)

Tuesday

The Solar Neighbourhood: the Importance of being Complete
Céline Reylé (Besançon Observatory); Davy Kirkpatrick (IPAC/Caltech); Daniella Bardalez Gagliuffi (Amherst College); Ricky Smart (INAF-OATo)

Solar-Stellar Eruption Analogy: Observations and Models
Yuta Notsu (University of Colorado Boulder); Kai Yang (University of Hawaii); Alison O. Farrish (NASA/GSFC); and Graham S. Kerr (NASA/GSFC and Catholic University of America)

The Buddy System: Utilizing the Wealth of Host Star Data to Inform Substellar Physics
Emily Calamari (CUNY/AMNH) and Austin Rothermich (CUNY/AMNH)

Thursday

Planet-Host Cool Dwarfs: Star-Planet Connection and Tracing Planetary Formation and Composition
Neda Hejazi (University of Kansas); Ian Crossfield (University of Kansas); Natalie Hinkel (Louisiana State University); Diogo Souto (Federal University of Sergipe); David Coria (University of Kansas); Emilio Marfil (Hamburger Sternwarte); Yakiv Pavlenko (Instituto de Astrofísica de Canarias); Katia Cunha (University of Arizona); Zachary Maas (Indiana University); and Zhoujian Zhang (UCSC)

Exoplanet Space Weather around Cool Stars
Donna Rodgers-Lee (Dublin Institute for Advanced Studies); Carolina Villarreal D'Angelo (Universidad Nacional de Cordoba); Gopal Hazra (Indian Institute of Technology Kanpur); Stefano Bellotti (Leiden University)

Magnetic Fields in the Sun and Low-mass Stars
Paul I. Cristofari (Harvard-Smithsonian Center for Astrophysics); Andrea K. Dupree (Harvard-Smithsonian Center for Astrophysics), Klaus G. Strassmeier (Leibniz-Institute for Astrophysics Potsdam); Jean-François Donati [Université de Toulouse, CNRS)

Abstracts

Plenary Talks

Monday

Disc, Outflow, and Protostar Formation in Low-Mass Dense Core Collapse

Benoît Commerçon
Centre de Recherche Astrophysique de Lyon | École Normale Supérieure de Lyon
Monday 8:45am

In parallel with the tremendous increase in high-resolution observations of young, low-mass protostars using the latest interferometers, significant progress has been made over the last ten years in our understanding of disk formation, outflows and protostars, thanks to multidimensional numerical simulations. Today, numerical experiments run on supercomputers and achieve unprecedented numerical resolution and temporal evolution. Using the results of recent 3D radiation magnetohydrodynamics simulations, I will review our current understanding of the formation and evolution of the protostellar disk, outflow and protostar through the different phases and scales of dense low-mass core collapse. I will show to what extent the results of numerical experiments can address the fundamental problems of angular momentum and magnetic flux conservation. Finally, I will detail the questions still open and give some perspectives on the next generation of numerical experiments.

Theme: New Insights into Star Formation and Evolution

How accurately can we measure young disk sizes and masses? A synthetic ALMA observation perspective

Ngo-Duy Tung
CEA | Paris-Saclay | CNRS
Monday 9:15am

Protoplanetary disks are the necessary consequence of the gravitational collapse of the dense molecular cloud cores and the subsequent birthplace of planetary systems. Numerous studies have investigated the properties of disks in the more mature Class II stage, either theoretically by numerical simulations from pre-defined initial conditions or observationally by modelling of their dust continuum and line emission from specific molecular tracers, and compared the results from the two standpoints. However, few have evaluated the main limitations at work when determining the embedded Class 0/I disk properties from continuum observations. In this talk, we present our first attempt to assess the accuracy of some critical disk parameters, namely their radii and masses, in Class 0 systems, as derived on actual ALMA observational data, with the corresponding physical parameters accessible to modellers in numerical simulations. To that ends, we followed the approach of performing full post-processing of the numerical simulations and applying on the synthetic observations the same techniques used by observers to obtain the physical properties. We then demonstrate how their sizes and masses vary from the gas kinematics analyses to the dust continuum modelling and provide implications for the possible uncertainties in the modelling of these objects from observations.

Role of the environment in star and planet formation: irradiated protoplanetary disks in Carina

Dominika Itrich
University of Arizona
Monday 9:30am

Most of our knowledge about how stars form comes from observations of the nearest star-forming regions. These all share similar properties (e.g., mass, density, radiation field, metallicity, etc.), and therefore do not give us representative picture of star formation in our Galaxy or in the Universe. Local environment may play a pivotal role in shaping future stars and their planetary systems. Specifically, massive stars can be particularly destructive to the circumstellar disks hosting young planets due to their strong UV radiation, which can remove matter from the disk. These harsh conditions are characteristic of massive star-forming regions such as the Carina Nebula Complex. Here, we present a spectroscopic study with VLT/MUSE of the population of young, low-mass stars in Carina and their disks by means of accretion. The UV radiation in Carina spans few orders of magnitudes, we assess the impact of environment on accretion properties testing their dependence on the level of the perceived UV radiation. We complement the investigation with measurements of forbidden atomic emission lines tracing disk photoevaporation. We discuss our results in the context of theoretical predictions of external photoevaporation and observational studies of other star-forming sites. Our findings support the scenario of externally evaporated disks and show that with available instruments a detailed spectroscopic study of young stellar populations is possible even in regions at large distances.

Theme: New Insights into Star Formation and Evolution

The formation of brown dwarfs in the most extreme environments of the Milky Way: Westerlund 1

Victor Almendros-Abad
National Institute for Astrophysics
Monday 9:45am

While the population of brown dwarfs has been extensively studied in nearby star-forming regions (d < 400 pc), theories of brown dwarf formation suggest that high gas or stellar densities, as well as the presence of massive OB stars, may stimulate the formation of brown dwarfs compared to stars. Therefore, it is imperative to extend the study of the brown dwarf population to massive young clusters, characterized by significantly different star-forming environments than those found in our immediate vicinity. One of such regions is Westerlund 1, located at a distance of 4 kpc and with an estimated mass of 52000 $M_\odot$, it is the closest supermassive star cluster to the Sun and possibly the most massive cluster in the Milky Way. We have recently obtained deep JWST/NIRCAM observations of Westerlund 1 within the EWOCS (Extended Westerlund 1 and 2 Open Clusters Survey) project. One of the primary goals of this project is to derive the mass function of the cluster and investigate whether the formation of brown dwarfs is influenced in such an extreme environment. In this contribution, I will present the NIRCAM products and the first results on the (sub)stellar initial mass function of the cluster, comparing it with recent studies on nearby star-forming regions and other massive young clusters in the Milky Way.

Theme: New Insights into Star Formation and Evolution

Theory for the Formation of Jupiter-Mass Binary Systems

Fred Adams
University of Michigan
Monday 10:00am

This paper presents a theoretical explanation for the collection of low-mass binary systems (with roughly Jovian masses) that were recently discovered in the Orion Nebula Cluster. In this scenario, binary systems are produced through the collapse of gas parcels with high densities $n \sim 10^7$ cm^{-3}, cold temperatures $T \sim 10$ K, and rapid rotation rates $\Omega \sim 30$ km s^{-1} pc^{-1}. With these initial conditions, a given parcel resides near the threshold for opacity limited fragmentation and has mass of order $M \sim 10\ M_{Jup}$. The parcel collapses to form a disk-like structure with centrifugal radius $R_C \sim 100$ AU, and the disk subsequently fragments into multiple bodies. This paper estimates the conditions required for initial collapse and disk instability, and outlines the parameter space for which binaries are the energetically favored outcome. A suite of numerical simulations is then carried out to illustrate the possible outcomes from disk fragmentation. The initial conditions required to form the observed binary systems lie at the extremes of the expected parameter distributions, but nonetheless can be realized within typical cluster environments.

Theme: New Insights into Star Formation and Evolution

Zooming-in on the innermost regions of a hundred protoplanetary disks with VLTI/GRAVITY

Karine Perraut
L'Institut de Planétologie et d'Astrophysique de Grenoble | Observatoire de Grenoble
Monday 11:00am

Deciphering the physical processes occurring in the inner region of protoplanetary disks is key to understanding the environmental conditions of (terrestrial) planet formation and evolution. Thanks to the exquisite performance of recent instruments, star-disk interactions can now be probed at sub-astronomical unit scales, providing a unique insight of the place where close-in planets are. Notably, with its unique milliarcsecond angular resolution, the near-infrared interferometric instrument GRAVITY of the VLTI has studied the 0.1–5AU central region in a homogeneous sample of a hundred protoplanetary disks around T Tauri, Herbig Ae-Be and high-mass young stars. This allows us to look for trends with the properties of the central star and the disk morphology within a statistical approach, and to investigate the connection with the well-known disk structures at larger scales within a multi-wavelength and multi-technique approach. Owing its high spectral resolution in the K-band, GRAVITY has spatially resolved in a sample of T Tauri stars the Br gamma emitting regions associated to hot hydrogen gas, which allowed us to differentiate between possible star-disk interaction mechanisms, and to directly monitor the magnetospheric accretion flows. The potential yield of the new GRAVITY+ upgrade, in particular towards the study of early Class I phases of YSOs in various star forming regions, will be discussed, as well as the possible legacy of GRAVITY(+) observations to refine theoretical physico-chemical models of disks.

Theme: New Insights into Star Formation and Evolution

Beyond the Veil: Perspectives on magnetospheric accretion in Classical T Tauri Stars

Hugo Nowacki
Univ. Grenoble Alpes | CNRS
Monday 11:30am

Some Classical T Tauri Stars (CTTS) are strong accretors ($\dot{M}_{acc}$ ~ a few 10^{-7} $M_\odot$/yr) , offering a unique opportunity to study magnetospheric accretion in a sustained regime (~100 times larger than in other CTTS). We present unique results from multi-technique observations of the strongly accreting CTTS S CrA N, offering a glimpse into the potential of the upcoming VLTI/GRAVITY+. This upgraded instrument will enhance sensitivity, making most CTTS accessible for near-infrared interferometry with a spatial resolution of a few stellar radii. Our observation of S CrA N, combining GRAVITY and CFHT/ESPaDOnS, unveils its dusty disk's sublimation front and magnetic topology, making possible a monitoring of accretion flows at a 1-hour cadence. GRAVITY+ promises to extend this capability to a larger CTTS sample, opening a statistical analyses era and enhancing comprehension of magnetospheric accretion. Combining GRAVITY+ with spectro-polarimeters like ESPaDOnS and SPIRou could broaden investigations to younger, more embedded sources, marking a milestone in near-infrared interferometry.

Theme: New Insights into Star Formation and Evolution

The most comprehensive NUV study of accretion onto classical T Tauri stars using HST ULLYSES

Caeley Pittman
Boston University
Monday 11:45am

Classical T Tauri stars coevolve with their surrounding protoplanetary disks, with the two being connected by the stellar magnetic field. Magnetospheric accretion of disk material onto the star is a primary driver of the system's evolution. It dictates the timescale of planet formation by removing disk material over time; it drives angular momentum transport; and it produces an accretion shock that irradiates the disk with NUV-dominated emission. This NUV continuum emission is observable only from space, and ground-based observables are less robust tracers of accretion. Therefore, we have undertaken the largest NUV accretion study of T Tauri stars using the Hubble UV Legacy Library of Young Stars as Essential Standards (ULLYSES) DDT Program as part of the ODYSSEUS and PENELLOPE collaborations. In this talk, I will present our results from consistently measuring the stellar and accretion properties of ~60 T Tauri stars using an accretion shock model. We find that ground-based studies systematically underestimate accretion rates by a factor of ~3 for a given T Tauri star. Further, on a population level, accretion rates are systematically underestimated for a given stellar mass. We propose a new $M_*-\dot{M}_{acc}$ relation based on our NUV accretion rate measurements, which increases the median $\dot{M}_{acc}$ by a factor of 5-6. We will discuss the implications of our work for models of disk dispersal and planet formation.

Theme: New Insights into Star Formation and Evolution

Mass dependence of convective envelope overshooting in pre-main-sequence stars

Mary Geer Dethero
Georgia State University
Monday 12:00pm

Improving stellar structure and evolution models is key to interpreting the high-quality stellar data produced by space missions like Kepler, TESS, and PLATO. We use the multi-dimensional, time implicit, fully compressible, hydrodynamic large eddy simulation code MUSIC (Multi-dimensional Stellar Implicit Code) to study how a star's mass affects the properties of stellar convection and overshooting. Stellar evolution models typically set the amount of overshooting using a fixed percentage of the pressure scale height. By comparing global simulations of convection in stars that have different masses, but identical evolutionary stages, we demonstrate that overshooting beneath a convective envelope is dependent on mass. This result extends the findings of recent observational (Claret and Torres 2018) and numerical (Baraffe et al 2023) studies that overshooting above a convective core is mass dependent. We also establish the mass dependence of other parameters that describe stellar convection, including the filling factor and the plume interaction parameter.

Theme: New Insights into Star Formation and Evolution

Accurate and Model Independent Radius Determination of Single FGK and M Dwarfs Using Gaia DR3 Data

Rocio Kiman
Caltech
Monday 12:15pm

Stellar age is a key fundamental property for understanding the habitability, evolution, and formation of exoplanets. In order to estimate precise ages, we also need to understand the evolution of more fundamental properties such as mass, radius and effective temperature. However, current theoretical models over-predict effective temperatures, and under-predict radii, compared to observations of M dwarfs (radius inflation problem), which are likely to host Earth-like exoplanets. In this talk I will present a model independent method to estimate stellar radii and how we used it to study the problem of radius inflation. We calibrated the Gaia surface brightness-color relation (SBCR) for low-mass stars which we combined with Gaia DR3 parallaxes to estimate radii. We found that radius inflation is correlated to magnetic activity for single stars, and we calibrated the percentage of radius inflation as a function of Hα emission and mass. This correlation could explain the difference between models and observations for M dwarf radii, and get us a step closer to understand M dwarf evolution.

Theme: New Insights into Star Formation and Evolution

Tuesday

The nearby census in the age of Gaia, and forthcoming large surveys

Céline Reylé
Observatoire de Besançon
Tuesday 8:45am

The nearest stars provide a fundamental constraint for our understanding of stellar physics and the Galaxy. The nearby sample serves as an anchor where all objects can be seen and understood with precise data. It provides benchmark stars and brown dwarfs that can be used to define calibration samples, as well as targets for focused planetary searches. The space mission Gaia and its unprecedented high precision parallax measurements gave the opportunity to refine the nearby census. The space mission Euclid and its large and deep near-infrared survey is poised to dramatically increase the census of the lowest mass stars and brown dwarfs in the Solar vicinity. I will review the recent efforts made to map the solar neighbourhood, to study the demographics of stars and substellar objects in our Galaxy.

Theme: Milky Way-scale Science and Big Data

Spectroscopic Survey Results of a Volume-Complete Sample of Mid-to-Late M Dwarfs within 15 pc

Jennifer Winters
Bridgewater State University
Tuesday 9:15am

We present results from a six-year campaign to gather multi-epoch, high-resolution spectra of an all-sky, volume-complete sample of 413 M dwarfs with masses 10-30% that of the Sun that lie within 15 parsecs. We report weighted mean systemic radial velocities and rotational broadening measurements (v sin i) for our targets. Our typical intra-star RV uncertainties are less than 30 m s^{-1} for the effectively single, slowly rotating targets in our sample, and are less than 1 km s^{-1} for more rapidly rotating stars. The majority of the presumed single stars in our sample (71± 3%) do not exhibit rotational broadening above our detection limit. Our radial velocities, combined with precise astrometric data, allow us to calculate Galactic space motions, with which we calculate thin and thick disk membership probabilities. We determine that the majority of our full sample (81%) are highly probable thin disk members. We report new multi-lined systems and identify additional targets with velocity variations indicative of long-period companions. Finally, we calculate multiplicity rates for our sample and find no significant difference between the stellar multiplicity rates of the thin disk and thick disk populations in our sample. Our survey more than triples the number of these fully-convective stars with both high-resolution spectroscopic and astrometric data.

Theme: Milky Way-scale Science and Big Data

Measuring the Detailed Chemistry of M dwarfs to Examine Planet Formation

Aida Behmard
American Museum of Natural History
Tuesday 9:30am

A star and its planets are born from a single cloud of gas and dust, so the chemical compositions of planet host stars encode information on the processes that govern planet formation. Measuring the compositions of M dwarf planet hosts is particularly important because the small sizes and masses of M dwarfs make them ideal for exoplanet discoveries. M dwarfs are also common, comprising ~70% of the stars in our galaxy. However, constraining M dwarf chemistry is a long-standing challenge; M dwarfs are cool enough for molecules to form in their atmospheres, which create complex spectral features that physical models struggle to reproduce. To solve this problem, I constructed the first-ever fully automated model for measuring M dwarf abundances across many elements with The Cannon, a data-driven framework. I will apply this model to Transiting Exoplanet Survey Satellite (TESS) M dwarf planet hosts with spectroscopic observations from the Sloan Digital Sky Survey (SDSS-V). This will enable us to explore connections between planet properties (e.g., occurrence rates, architectures) and M dwarf host chemistry, and thus shed light on dominant planet formation pathways around the most common stars.

Theme: Milky Way-scale Science and Big Data

Atmospheric parameters and chemical abundances in nearby stars

Ricardo López Valdivia
Universidad Nacional Autónoma de México
Tuesday 9:45am

In this talk, I present the determination of basic atmospheric parameters and chemical abundances in 1600+ main-sequence stars within 100 pc of the solar neighborhood. We used APOGEE-2 infrared spectra and a specially developed spectral fitting code called tonalli. We then used those atmospheric parameters in combination with a list of 35 atomic lines and the BACCHUS code to determine the abundance of Mg, Al, Si, Ca, and Fe in our sample. Our results indicate that atmospheric parameters determined with tonalli agree with previous determinations like those made by ASPCAP or Gaia DR3 for G, K, and M type stars (T_{eff} between 6000 and ~3200 K). tonalli allows us to obtain atmospheric parameters primarily from the stellar spectra without introducing a posteriori calibration. We established an infrared color-temperature relation that can be used to determine the temperature of any main-sequence star, a great alternative to characterize large stellar samples. Additionally, the characterization we made for our sample is a valuable resource for training neuronal networks or machine learning codes. We have applied our methods to a sample of more than 500 young stars in four groups (Orion A, B, OB1, and λ Ori) of the Orion complex. Our initial findings show no significant differences in the chemical abundances of stars from different Orion groups, suggesting that the Orion complex is chemically homogeneous in the five elements examined in this study.

Theme: Milky Way-scale Science and Big Data

Measuring Fundamental Stellar Parameters with ASAS-SN Eclipsing Binaries

Dominick Rowan
The Ohio State University
Tuesday 10:00am

Detached eclipsing binaries are the most precise method to measure fundamental stellar parameters. Starting from binary star candidates identified by the All-Sky Automated Survey for Supernovae (ASAS-SN), we use PHOEBE to determine the sum of the fractional radii, the ratio of effective temperatures, the inclinations, and the eccentricities for more than 35,000 detached eclipsing binaries. By combining our results with Gaia distances and 3-dimensional dust maps, we examine the properties of the systems as a function of their absolute magnitude and evolutionary state. We visually inspect all the light curves to verify the model fits and use TESS light curves to identify and characterize 766 binaries with evidence for “extra physics”, such as spots, pulsations, and doubly-eclipsing binaries. Finally, we use radial velocities to measure masses and radii of eclipsing red giants, which are vastly underrepresented in current catalogs. We start with Gaia DR3 spectroscopic orbits and measure the masses of 61 binaries, including 12 red giants. We are performing dedicated spectroscopic follow-up for an additional 20 eclipsing red giants.

Theme: Milky Way-scale Science and Big Data

Revisiting young associations in the age of Gaia with the Montreal Open Clusters and Associations database

Jonathan Gagné
Planétarium Rio Tinto Alcan | Espace pour la vie
Tuesday 11:00am

I will present some recent development in the study of coeval populations of stars in our neighborhood of the Galaxy, most of which were made possible by the advent of the Gaia mission. I will demonstrate the newly released Montreal Open Clusters and Associations (MOCA) database, a new resource for the community that includes a large number of observables and calculated properties for approximately 500,000 stars in 5,000 nearby associations and open clusters, comprising many stellar associations that were only recently discovered. I will also go over some of the online tools that we made available to the public at www.mocadb.ca, allowing users to explore the database in an interactive manner, or to connect directly via simple Python scripting, and will outline some of the current projects that rely on MOCAdb to further the census of nearby young stars, planemos and age-calibrated exoplanets. I will end with future progress on these topics that will be made possible with future missions such as the final Gaia data releases, the Rubin observatory, the Roman space telescope and the Euclid mission.

Theme: Milky Way-scale Science and Big Data

The SPYGLASS Program: Mapping the Dynamics and Evolution of Star Formation up to Galactic Scales

Ronan Kerr
University of Texas at Austin
Tuesday 11:30am

Young associations record star formation histories spanning tens of millions of years, revealing the initiation, progression, and termination of star formation long after the dispersal of the natal cloud. Through the SPYGLASS program, I am expanding this record by mapping the extensive and often poorly characterized network of clusters and associations in the solar neighborhood. Our most recent survey update reveals 116 young associations within 1 kpc in Gaia DR3, providing a powerful resource for studies of large-scale population statistics as well as star formation patterns on both local and spiral arm scales. I have already spectroscopically observed members of over a dozen young associations in this sample, providing radial velocities and youth indicators that can reconstruct entire star formation histories through age measurements and kinematic traceback. Results in two young associations have already revealed distinct nodes in which co-spatial star formation takes place, which may represent the clearest discrete unit of star formation. I am currently reconstructing star formation patterns in the much larger associations of Cep-Her and Sco-Cen, which are bridging the gap between local star formation and the patterns that drive star formation on galactic scales. Combining large-scale surveys with regional reconstructions of star formation, I am revealing processes guiding star formation ranging from local association scales to the scale of galactic structure.

Theme: Milky Way-scale Science and Big Data

Exploring Galactic Stellar and Dust Structures through Empirically Calibrated Isochrones

Deokkeun An
Ewha Womans University
Tuesday 11:45am

We present a novel approach for empirically calibrating synthetic spectra of main-sequence stars and apply it to extensive survey databases for investigating Galactic stellar and dust structures. Our method involves comparing synthetic spectra with observations of cluster sequences and individual stars with spectroscopic data, providing a first-order correction to theoretical models. By applying these calibrated models, we derive metallicities of stars from various photometric databases and construct chemo-dynamical distributions of Galactic stars by combining our data with Gaia astrometry. In particular, they unveil a remarkably narrow sequence in metallicity versus orbital rotational velocity space for high proper-motion stars. This observation lends support to a scenario suggesting a starburst during the Milky Way's encounter with the progenitor of Gaia Sausage/Enceladus, which eventually led to the deposition of metal-enriched gas onto the disk. In addition, we construct an all-sky three-dimensional extinction map from the largest collection of low-resolution spectra in Gaia DR3 by determining both the reddening and metallicity of main-sequence stars along each line-of-sight, which extends up to 3 kpc from the Sun. We discuss the implications of our technique in relation to future large photometric surveys, particularly considering its potential contributions to upcoming endeavors such as the LSST.

Theme: Milky Way-scale Science and Big Data

Wrinkles in Time: Tracing Spiral Arm Passages Using Gyrochronology

Rayna Rampalli
Dartmouth College
Tuesday 12:00pm

Recent space-based missions have ushered in a new era of observational astronomy, where high cadence photometric light curves for millions of stars in the solar neighborhood can improve our understanding of the Milky Way's dynamical history. One open problem in Galactic dynamics is understanding the timescale on which the Galaxy's spiral arms pass through the Solar Neighborhood. Simulations have shown that spiral arms can leave signatures, or "wrinkles", in kinematic-space, which are now observationally confirmed with high precision kinematic data from the Gaia mission. However, kinematics alone is not sufficient to disentangle the history of spiral structure. Using photometry from TESS and gyrochronology age-rotation relations, we are calculating stellar age distributions in wrinkles to place a timestamp on transient spiral arm passages. We have built a series of TESS rotation period measurement and validation pipelines that were tested on 1200+ stars with average recovery rates of 88% (Rampalli+2023). We apply these pipelines to measure periods for and determine gyro ages for ~34,000 TESS stars in non-wrinkle and wrinkle space. We pair gyrochronologically-determined ages with Ca II activity measurements from Gaia and Li measurements from Galah to ascertain youth of rapidly rotating stars. We present an age distribution of stars that place constraints on when spiral arm passages occurred. Early evidence suggests these passages could have happened as recently as 120 Myr ago.

Theme: Milky Way-scale Science and Big Data

Low-Mass, Unresolved Binaries identified from their Gaia XP Spectra

Zach Way
Georgia State University

Tuesday 12:15pm

Fundamental parameters of low-mass stars (temperature, mass, metallicity) can potentially be determined by their location on an HR diagram with sufficiently accurate photometry and parallaxes. This is, however, complicated by the fact that 20-40 percent of low-mass stars are predicted to be unresolved binaries and appear more luminous compared to single stars with comparable fundamental parameters. We present a method to separate out the binary stars from the single-star main sequence K and M dwarfs with their Gaia DR3 XP spectra. Using Gaia DR3, we create a sample of stars with pristine astrometry and photometry composed of single stars and equal mass binaries within 100 parsecs. We then iteratively train Random Forest Regression (RFR) models to predict absolute magnitude and color given a star's RP spectral coefficients. After each model, we remove the stars which are predicted to be significantly dimmer than their measured absolute magnitude from training future models. This method converges on an RFR model trained only on the single stars within the 100 parsec sample. We then use this model to predict the absolute magnitudes of the full 200 parsec sample of K and M dwarfs and find that 29 percent of the sample is significantly more luminous than our prediction. This method provides a novel approach at breaking the multiplicity-metallicity degeneracy of the lower main sequence and can be a useful tool for wide-field surveys to predict the multiplicity of a given source.

Theme: Milky Way-scale Science and Big Data

Wednesday

Solar Wind Sources and Acceleration: Insights from Parker Solar Probe and Solar Orbiter

Marco Velli
Institute of Geophysics and Planetary Physics | University of California Los Angeles
Wednesday 8:45am

The solar magnetic field plays a dual role in the generation of the Heliosphere. On the one hand it creates the corona by storing and transmitting, via a Poynting flux crossing the photosphere and transition region, the energy provided by the dynamo and convective motions; on the other hand, it provides the confinement, or magnetic cage, through which the heated coronal plasma must break through - everywhere except solar polar regions around solar minimum - to produce the supersonic solar wind. Solar wind streams are characterized by different plasma properties, from overall speed, to temperature and temperature anisotropies, composition, as well as different properties for the embedded turbulence. While it has been established that the source of fast solar wind streams at solar minimum are the polar coronal holes, slower solar wind streams have contributions from different sources. The larger than expected filling factor of slow solar wind has been attributed to flows coming from coronal hole boundaries, i.e., regions with large expansion factors, or from the complex mapping of the magnetic field from the photosphere into the heliosphere, i.e. the S-Web, or squashing factor. The observation by Parker Solar Probe that much of the solar wind, independently of speed, is dominated by Alfvénic fluctuations, and the frequent observation of slow Alfvénic solar wind, previously observed relatively rarely in Helios and Wind data, provide evidence for a modified picture of solar wind origins.This contribution reviews the origin and acceleration of different types of solar wind streams throughout the solar cycle, and how Parker Solar Probe and Solar Orbiter have helped change and integrate our understanding.

Theme: The Sun and Cool Stars in the Time Domain

Observation-driven wind models reveal the spin-down bimodality in solar-type stars

Dag Evensberget
Leiden Observatory
Wednesday 9:15am

The diverse rotational velocities of solar-type stars at birth, and their evolution, present a compelling puzzle. Traditional models based on polytropic stellar winds have fallen short in explaining the observed transition from a broad range of initial rotational speeds to the well-documented Skumanich spin-down phase, without resorting to arbitrary limits on the wind mass-loss rate. To shed light on this issue, we carried out a set of Alfvén wave powered wind simulations covering the Sun and twenty-seven open cluster stars, aged between 0.04 to 0.6 Gyr, all of which are characterized by observationally derived surface magnetic maps and rotation rates. The results are revealing: we observe torques and mass loss rates compatible with an exponential spin-down among young, fast-rotating stars, transitioning to the Skumanich spin-down in their older, slower counterparts. Remarkably, this bifurcation in spin-down behaviour emerges naturally from our model, without the need for predefined limits on wind mass loss. The findings of this study suggest that the observed distribution of stellar rotation rates may be a direct consequence of magnetic field strength saturation in faster rotators. Furthermore, our work offers new insights into the interplay between stellar magnetic fields and wind dynamics, enhancing our understanding of the processes driving stellar spin-down. This research charts a course for future explorations into the magnetic mechanisms influencing stellar rotation.

Theme: The Sun and Cool Stars in the Time Domain

Witnessing magnetic field cycles: long-term spectropolarimetric monitoring of BCool solar analogs

Stefano Bellotti
Leiden Observatory
Wednesday 9:30am

The 22-yr-long solar magnetic cycle consists of two consecutive 11-yr sunspot cycles, and exhibits a polarity reversal at sunspot maximum. The large scale magnetic field is complex at cycle maximum, and assumes a more simple, dipolar geometry at minimum. Although solar dynamo theories have progressively become more sophisticated, the details as to how the dynamo operates and sustains magnetic fields are still subject of research. In this context, observing the magnetic field evolution of Sun-like stars advances our understanding on how key dynamo ingredients, like stellar mass and rotation, influence internal dynamo processes. In this talk, I present the long-term spectropolarimetric monitoring of six Sun-like stars performed within the BCool programme. The masses of our stars are at most 6 percent larger than solar and the rotation periods span 3.5-21 d, so it is a practical sample to study magnetic evolution for Sun-like interiors and distinct activity levels. We applied Zeeman-Doppler imaging to map the large-scale stellar magnetic field from circular polarisation spectra collected with ESPaDOnS and Narval over 10-15 yr. We found that our solar analogs exhibit a dipolar field with clear polarity switches over 3-11 yr, while our fast-rotating stars have a complex, temporally stable field topology, with oscillations in field strength. These results emphasise the sensitivity of magnetic cycles to stellar fundamental parameters, specifically the stellar rotation period.

Theme: The Sun and Cool Stars in the Time Domain

The Sydney Radio Star Catalogue and radio variability of cool dwarfs

Laura Driessen
Sydney Institute for Astrophysics | University of Sydney
Wednesday 9:45am

I will present a new catalogue of ~800 radio stars detected at <2 GHz: the Sydney Radio Star Catalogue (SRSC). Approximately half of the stars in the catalogue have multiple radio detections, revealing information about the variability of radio stars. Many of the stars are K and M dwarfs, as well as some ultra-cool dwarfs. The previous best-known radio star catalogue, the Wendker catalogue, contained approximately 200 radio stars detected at <2 GHz. This means that the population, properties and variability of radio stars are not well known. If a star is detected in the radio this provides information about the chromosphere, the magnetic fields and potential impact on orbiting exoplanets. Stellar radio variability tells us more about these properties, as well as rotational velocities, different emission mechanisms, and activity cycles. For example, the Variables and Slow Transients (VAST) survey with the Australian SKA Pathfinder (ASKAP) has been observing Galactic Fields every few weeks for more than a year and will continue to do so for three more years. VAST provides unprecedented monitoring for stars in those fields. I will present properties of the population of radio stars in the SRSC and the light curve variability of individual cool stars. We are excited to share the potential of radio observations to reveal properties of the radio star population and to study individual objects.

Theme: The Sun and Cool Stars in the Time Domain

Measuring Sub-Kelvin Variations in Stellar Temperature

Étienne Artigau
Université de Montréal
Wednesday 10:00am

This presentation introduces a novel method to measure stellar activity through precise differential temperature measurement. The method is inspired by precision radial velocity algorithms, used in the temperature space; they lead to a sub-Kelvin accuracy, using the correlated changes in fractional depth of all spectroscopic features in a given spectrum. The technique is based on a library of spectra with known temperatures, enabling the derivation of temperature changes and uncertainties for each spectral line and a combined differential temperature accuracy that is unprecedented and opens a new tool for stellar physics. We demonstrate the power of this technique by retrieving rotation periods of inactive stars (e.g., Barnard star), in retrieving the starspot evolution in moderately active stars (e.g., Proxima, Epsilon Eridani) as well as very young objects (e.g., AU Mic). We also showcase the detection of an equivalent to the detection of the Rossiter effect in temperature space, where a transiting planet changes the disk-averaged temperature of the host star, providing a unique constraint on the geometry of exoplanet systems.

Theme: The Sun and Cool Stars in the Time Domain

Precision "Sun-as-a-Star" Spectra

Lily Zhao
Flatiron Institute | Center for Computational Astrophysics
Wednesday 11:00am

The radial velocity (RV) scatter that arises due to time-varying inhomogeneities on stellar surfaces is now the largest source of error for the dynamical detection and characterization of exoplanets. As such, a host of different mitigation methods exist with the goal of disentangling stellar signals from spectral shifts due to orbiting planets. I will present contemporaneous Sun-as-a-star observations taken by HARPS, HARPS-N, EXPRES, and NEID and discuss the potential and limitations of this combined data set for testing mitigation methods. I will give an overview of current mitigation methods employed as part of the Extreme Stellar Signals Project (ESSP), an international research network of scientists developing such methods. I will conclude with a framework showing the existence of a low-dimensional latent space that can capture relevant stellar surface variation in the spectral domain.

Theme: The Sun and Cool Stars in the Time Domain

Transient Corotating Gas Clumps Around Adolescent Low-Mass Stars

Luke Bouma
Caltech
Wednesday 11:30am

Space-based photometric surveys have shown that one to a few percent of cool stars younger than 200 million years exhibit complex, but highly structured and periodic optical light curves. The most likely interpretation for these
complex periodic variables", after correcting for the line-of-sight viewing angle, is that up to a quarter of young cool stars host transient circumstellar clumps of material that can be magnetically confined to corotate with the star for hundreds of rotation cycles. The composition of this material is not currently known: dust would suggest an extrinsic origin (e.g., debris from planetesimal collisions), while partially-ionized gas could suggest an intrinsic origin (e.g., a stellar wind). After summarizing the existing body of evidence, I will highlight how a new census using TESS has yielded the brightest and closest complex periodic variables known. We have acquired simultaneous time-series optical spectroscopy and photometry of these new objects, and we are finding that the circumstellar clumps of material contain significant quantities of hydrogen. This rules out "dust-only" scenarios, and implies either a purely stellar origin for the phenomenon, or a mixed-composition scenario in which both gas and dust are present.

Theme: The Sun and Cool Stars in the Time Domain

Radio search for extrasolar coronal mass ejections and eruptive flares

David Konijn
ASTRON
Wednesday 11:45am

Coronal mass ejections (CMEs) are a dominant contributor to space weather in the solar system, with the potential to catastrophically erode planetary atmospheres. Traditional stellar activity probes, such as flares, cannot indicate if a CME is present. A characteristic radio burst (called type-II burst) is an unambiguous CME signature but there have been no such bursts detected due to a lack of sensitivity and time on sky. I will show that by using the solar flare-CME relationship, we should be able to find >50 type-II bursts within the Low-Frequency Array Two-Metre Sky Survey. I will present a progress report of our ambitious project to search over 12 petabytes of data to identify extrasolar CMEs. In particular, I will present our discovery of the first extrasolar type II burst, which contains the first unambiguous CME signatures, detected by the Low-Frequency Array. Lastly, I will end with presenting plans for a more ambitious search to discover extrasolar (so-called) type-III bursts that trace energetic particle events.

Theme: The Sun and Cool Stars in the Time Domain

A population of Dipping Giant Stars in the Nuclear Disc of the Milky Way

Philip Lucas
University of Hertfordshire
Wednesday 12:00pm

A recent investigation of the highest amplitude infrared variable stars in the Milky Way discovered an unexpected new population of giant stars that show multi-year dips of several magnitudes in their light curves. Intriguingly, the stars are strongly clustered in the Nuclear Disc of the Milky Way, which co-locates with the Central Molecular Zone (CMZ). These dips seen in the 10 year VVV light curves are asymmetric, showing somewhat disparate profiles and at present there is no evidence that they are periodic events. Spectra suggest that these stars have super-solar metallicities which would be consistent with the Nuclear Disc location. Following the initial discovery of 21 dipping giants, further searches of the VVV data have found many more examples with lower amplitudes, tracing out a spatial structure slightly offset from the Galactic Centre, somewhat resembling the structure of the CMZ. The stars appear likely to be on the Asymptotic Giant Branch but they do not pulsate. The colour-magnitude behaviour indicates extinction by sub-micron grains but Spitzer photometry rules out any large envelope of cool circumstellar matter. We place these discoveries in the context of past work and discuss two possible explanations for the phenomenon: (i) dust puffs in the line of sight, similar to R Cor Bor stars and (ii) long period eclipses by circumstellar matter associated with a companion.

Theme: The Sun and Cool Stars in the Time Domain

The First Empirical Gyrochronology Relation for Single Field Stars > 4 Gyr

Yuxi (Lucy) Lu

American Museum of Natural History
Wednesday 12:15pm

Gyrochronology, the field of age-dating stars using mainly their rotation periods and masses, is ideal for inferring the ages of individual main-sequence stars. However, modern gyrochronology relies heavily on empirical calibrations, and the lack of old benchmark ages for main-sequence stars means no gyrochronology models have been calibrated for stars older than 4 Gyr. In this talk, we present the first empirical gyrochronology relation capable of inferring ages for single, main-sequence stars between 0.67 Gyr to 14 Gyr, using a Gaussian Process model conditioned on kinematic ages (~ 1 - 14 Gyr) and known clusters ages (0.67 - 3.8 Gyr). I will show this model is self-consistent with wide-binary pairs and has an average uncertainty of just over 1 Gyr with asteroseismic ages. With this model, I will showcase the largest gyrochronology age sample for ~ 100,000 stars within 1.5 kpc of the Sun with period measurements from Kepler and ZTF, and 353 unique planet host stars.

Theme: The Sun and Cool Stars in the Time Domain

Thursday

Unveiling the Stellar Properties of M Dwarfs: Current Progress and Future Directions

Bárbara Rojas-Ayala
Universidad de Tarapacá
Thursday 8:45am

This presentation delves into the intricate task of unraveling the stellar properties of M dwarfs, shedding light on both the current achievements and the future pathways in this challenging endeavor. The pursuit of exoplanets orbiting M dwarfs has ignited a renewed interest in their stellar characteristics, propelling advancements in observational techniques and theoretical models. We navigate through various methodologies employed to extract fundamental parameters of these low-mass stars, with particular emphasis on the pivotal role played by binary/multiple systems and benchmark samples in understanding their intrinsic nature. Despite the significant progress made, challenges persist, notably in reconciling discrepancies between methodologies. However, it is precisely these challenges that motivate our collective efforts to overcome them in the near future. Interdisciplinary collaborations persist in propelling us towards a holistic understanding of M dwarfs and their roles as stellar hosts. This journey not only enriches our comprehension of individual stars but also deepens our understanding of planetary systems and our Galaxy at large.

Theme: Cool Stars as Stellar Systems

Surveying Orbital Architectures -- Big and Small -- for the Histories of our M Dwarf Neighbors

Eliot Halley Vrijmoet
Smith College
Thursday 9:15m

Although we are accustomed to considering binary star systems in terms of their immediately observable properties such as separation, their full orbits reveal a much richer picture. This context is particularly difficult to achieve for the lowest-mass stars because mapping their orbits takes more time for a given semi-major axis. We present our multi-method survey -- astrometric, visual, and spectroscopic -- of ~200 M dwarf multiples in the solar neighborhood, from which we compare the orbits of systems with respect to their masses, mass ratios, and orbital periods. With these orbits that span 1 day to 30 years, our goal is to contextualize these systems' dynamics -- to reveal their behavior as a population. We find that orbits longer than a few years tend to be more eccentric if the stars are more massive, indicating a mass-dependent difference in the environments that drove these systems' early dynamical evolution. Along the same lines, M dwarfs' orbits are less eccentric than those of FGK binaries. The eccentricity distribution does not depend strongly on mass ratio or whether or not a given pair has a third companion. These orbits also constrain the tidal circularization period for M dwarf pairs at ~7 days, shorter than that of FGK binaries. In this talk we will expand on these results in the context of the completeness of the parameter space thus far, and in particular the questions that remain open around lowest-mass stars and their lower-mass companions.

Theme: Cool Stars as Stellar Systems

A JWST binary survey at the cold and low-mass end of star formation

Clémence Fontanive
Institute for Research on Exoplanets | University of Montréal
Thursday 9:30am

As binarity is a direct outcome of formation, studying multiplicity across all ranges of masses and separations is key to fully understand stellar formation mechanisms. Here, we present results from a JWST/NIRCam+NIRISS campaign aimed at investigating the multiplicity of the coldest and least massive objects produced by star-forming processes. We searched for close binary companions to 22 nearby Y-type brown dwarfs, all cooler than 500 K, that represent the bottom end of the observed Initial Mass Function in the Solar neighborhood. One binary system, WISE 0336 AB, was discovered in our search and represents the first Y+Y binary system. With an estimated temperature of smaller than 300 K, the companion bridges the gap between the coldest known brown dwarf, WISE 0855, and the rest of the Y-type population. Thanks to JWST's exceptional infrared sensitivity to extremely cold objects, and its unmatched spatial resolution at these wavelengths, we placed strong constraints on the multiplicity outputs of star

formation inside unexplored regions of the parameter space, allowing to test whether the trends in companion occurrence rate, separation and mass ratio distribution seen for more massive objects extend down to the very lowest masses and temperatures.

Theme: Cool Stars as Stellar Systems

Revealing the Exoplanet Radius Distribution in Binary Star Systems

Kendall Sullivan
University of California, Santa Cruz
Thursday 9:45am

Small planets ($R_p < 4R_\oplus$) are divided into rocky super-Earths and gaseous sub-Neptunes separated by a radius gap, but the mechanisms that produce these distinct planet populations remain unclear. Binary stars are the only main-sequence systems with an observable record of the protoplanetary disk lifetime and mass reservoir, and the demographics of planets in binaries may provide insights into planet formation and subsequent evolution. To investigate the radius distribution of planets in binary star systems, we observed 190 binary systems hosting 264 confirmed and candidate transiting planets detected by the Kepler mission and recharacterized the planets while accounting for the observational biases introduced by the secondary star. We found that the population of planets in close binaries ($\rho \leq 100$ au) is significantly different from the planet population in wider binaries ($\rho \geq 300$ au) or single stars. In contrast to planets around single stars, planets in close binaries appear to have a unimodal radius distribution with a peak near the expected super-Earth peak of $R_p \sim 1.3\ R_\oplus$ and a suppressed population of sub-Neptunes. We conclude that we are observing the direct impact of a reduced disk lifetime, smaller mass reservoir, and possible altered distribution of solids reducing the sub-Neptune formation efficiency.

Theme: Cool Stars as Stellar Systems

Using Star-planet Interactions to Determine Planet Magnetic Fields: Case of YZ Ceti

Sebastian Pineda
LSAP | CU Boulder
Thursday 10:00am

Exoplanetary magnetic fields play an important role in modulating atmospheric mass-loss and potentially shielding the atmosphere from the impact of energetic particles in the stellar wind. The planetary fields are an important ingredient in assessing the prospects for habitability; however, there remains few empirical constraints on exoplanetary magnetic properties. The

recent detections of radio emission from the nearby exoplanet host, YZ Ceti, suggest that the star is possibly interacting with its rocky innermost planet. These radio emissions are characterized by strong circular polarization, and appear to repeat within consistent orbital phase windows dictated by the orbital position of YZ Ceti b. The strength of the radio bursts are further consistent with theoretical predictions of the star-planet interaction. We will discuss our ongoing efforts to characterize this system and test potential alternative interpretations of the radio emissions. Our efforts in fully characterizing the magnetic properties of the star with spectropolarimetry will let us transform the radio detections into bona fide constraints on an exoplanet magnetic field. Understanding the interactions of stars with planets requires an interdisciplinary systems approach. The advent of radio star-planet interactions illustrates how radio observatories will make significant advances at this vanguard of understanding planet magnetic fields, habitability, and the different kinds of extrasolar magnetospheres.

Theme: Cool Stars as Stellar Systems

Magnetic fields in Sun-like and low-mass stars

Ansgar Reiners
Georg-August-Universität Göttingen | Institut für Astrophysik und Geophysik
Thursday 11:00am

Magnetism is among the most relevant and exciting physical mechanisms in the Sun and cool stars. Its ramifications are ubiquitous, yet its observational characterization and modeling pose significant challenges. The talk will provide an overview about our current understanding of magnetic field generation and magnetic activity in Sun-like and low-mass stars. Special focus will be placed on delineating the interplay between various magnetic field and activity indicators that can be useful for understanding magnetism and characterizing activity-induced stellar variability.

Theme: Cool Stars as Stellar Systems

On Convective Turnover Times In Low-Mass Stars

Seth Gossage
CIERA | Northwestern University
Thursday 11:30am

The relationship between magnetic activity and Rossby number---the rotation period divided by the "convective turnover time" is well-established for low mass stars (roughly F-type and later). However, in present stellar evolution models convection is largely a simplified theoretical phenomenon rather than an observational one, and our understanding of both stellar convection

and magnetic dynamos is still incomplete. In the Rossby-activity relation, it is generally assumed that the convective turnover time should be calculated near the base of the convective envelope in low mass stars, which in turn is based on the assumption that the dynamo is situated there as well. Using 1D stellar evolution models, we have re-calibrated the convective turnover time vs stellar mass relationship. Taking the Rossby-activity relationship as ground truth, we use measured stellar X-ray luminosities and rotation periods to derive empirical convective turnover times. By comparison with model turnover times as a function of depth in the stellar envelope, we can locate the (implied) predominant region of dynamo activity within the envelope. I will present results that suggest that the dynamo does not lie at the base of the convection zone (or tachocline) for all low mass stars. I will also discuss the convective turnover times themselves, and in particular the problematic stellar masses around the fully-convective limit.

Theme: Cool Stars as Stellar Systems

The extended corona of a young Sun: Combined VLBI/spectropolarimetry observations

Clara Brasseur
University of St. Andrews
Thursday 11:45am

Understanding stellar magnetic fields is crucial to understanding the structure and evolution of stars. While there are ways to observe the surface magnetic field of a star, it is more difficult to detect the structure of the magnetic field above the surface in the corona. In this talk I present the results of our multiwavelength study of the young (~40-50 Myr) solar-like star AB Doradus, where we find that it has an extended corona of ~8-10 stellar radii. I describe how we use the surface magnetic field map derived from spectropolarimetry to produce a 3D extrapolation of AB Dor's coronal magnetic field, from which we create synthetic radio images. I discuss how we compare our synthetic images with approximately simultaneous radio interferometry observations that show complex structures around AB Dor. I show that we are able to reproduce the observed radio flux and the morphology of the derived radio images, and discuss the implication of such a large coronal extent in young stars.

Theme: Cool Stars as Stellar Systems

Catching the wisps: constraining mass-loss rates of cool stars at low frequencies

Sanne Bloot
ASTRON

Thursday 12:00pm

Stellar winds govern the lives of stellar systems, from dictating the evolution of the star itself to eroding the atmospheres of exoplanets. The impact of the wind on a stellar system is largely determined by the mass-loss rate -- which is notoriously difficult to measure on dwarf stars since the wind is so tenuous. Currently, mass-loss rates of cool stars have to be modelled or inferred indirectly, for example from astrospheric Ly α absorption. In this talk, I will present a more direct method to constrain the mass-loss rate of a star using detections of low-frequency coherent radio emission, exploiting the lack of free-free absorption to place upper limits on the stellar mass-loss rate. We apply this method to M dwarfs detected with LOFAR at 120 MHz and find upper limits down to 4 times the solar mass-loss rate, independent of distance. While these limits are already competitive with other methods, we expect to reach upper limits of less than the solar mass-loss rate in the near future.

Theme: Cool Stars as Stellar Systems

Stellar Flares in the Ultraviolet with GALEX

Vera Berger
University of Cambridge
Thursday 12:15pm

Ultraviolet (UV) emission from stellar flares plays a crucial role in determining the habitability of exoplanetary systems. Flare UV emission may drive prebiotic chemistry, erode planetary atmospheres, or produce false biosignatures. In this talk, I will present the first statistical analysis of stellar flares with simultaneous observations in NUV and FUV. We identify 182 flares on 158 stars within 100 parsec of the Sun in both the near-ultraviolet (NUV: 1750-2750 \AA) and far-ultraviolet (FUV: 1350-1750 \AA) using high-cadence light curves from the Galaxy Evolution Explorer (GALEX). We show for the first time that uniformly selected stellar flares are far-ultraviolet luminous. We explore tentative trends of FUV/NUV energy ratio with respect to spectral type and total UV flare energy. We find that widely used assumptions for flare emission significantly underestimate the levels of FUV emission we observe. We construct empirical models for flare light curves in the NUV and FUV, and compare to the classical optical template for flares. I will discuss the implications for photochemical modeling of stellar activity and planetary atmospheric chemistry, the search for accurate biomarkers, and future missions to observe stellar flares in the ultraviolet.

Theme: Cool Stars as Stellar Systems

Friday

Looking Back at the Last 30 Years of Brown Dwarf Research and Looking Forward to Opportunities Ahead

Davy Kirkpatrick
Caltech | Infrared Processing and Analysis Center
Friday 8:45am

The last three decades have seen the field of brown dwarfs grow from the discovery of the first examples by a relatively small group of active investigators to a vibrant area of research with >1000 examples being studied via scores of different groups. Once a unicorn, the brown dwarf has proven to be far more than just an inert by-product of star formation. Instead, it has much to inform us about the creation of low-mass star-like products, the growth of dust/grains in cold atmospheres, the broader interpretation of results from exoplanet studies, and much more. In this talk, I will provide a brief retrospective on the search for the first brown dwarfs, then rapidly pivot to a summary of our current understanding of their properties. I will also discuss pros and cons of the two definitions of brown dwarfs, along with an admonishment (somewhat self directed) for referring to such objects as "failed stars". Finally, I'll outline the major outstanding questions in the field and highlight a few current and upcoming surveys that should help us provide the answers.

Theme: Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

Sonora Diamondback: Cloudy Atmosphere and Evolution Models for Brown Dwarfs and Giant Planets

Caroline Morley
University of Texas at Austin
Friday 9:15am

Accurate evolution models are critical for tying observable properties (e.g., luminosity) of substellar objects to key properties like mass. The thermal evolution of brown dwarfs and planets is regulated by their atmospheres, which allow their heat of formation (and from the brief era of energy generation from deuterium fusion) to radiate to space for billions of years. We present a new generation of atmosphere and evolution models which include the effects of clouds for warm substellar objects. We show how silicate (plus iron and corundum) clouds change the spectra of exoplanets and brown dwarfs in objects from 900--2400 K at a range of surface gravities. We include, for the first time in our cloudy modeling framework, three metallicities including super-solar (+0.5, similar to Jupiter) and sub-solar (-0.5) and demonstrate that these can change the evolution models substantially at some ages. We show how the emergence and disappearance of clouds affects the evolution of planets, creating a new set of "hybrid" evolution models applicable for giant planets and brown dwarfs. Our models have key

upgrades from prior generations, including updated chemistry and opacities, and we present medium-resolution spectra (applicable for JWST, and other, applications) and high-resolution spectra appropriate for echelle spectroscopy from the ground.

Theme: Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

A Metallicity Classification System for T Subdwarfs

Adam Burgasser
University of California, San Diego
Friday 9:30am

We present a metallicity classification system for T dwarfs based on previously identified metal-poor brown dwarfs and new discoveries made by the Backyard Worlds: Planet 9 project. We define three metallicity classes in the near-infrared to augment the current dwarf sequence: mild subdwarfs (d/sdT), subdwarfs (sdT), and extreme subdwarfs (esdT), with sets of spectral standards that define individual subtypes. We demonstrate how this sequence encodes both temperature and metallicity variations among the currently known sample of metal-poor brown dwarfs, and define a metallicity index analogous to the ζ index for M subdwarfs to quantify metallicity classification. We also use spectral model fits to infer metallicities for these classes, benchmarked to companions of stars with known compositions. This sequence is a necessary advance as more metal-poor brown dwarfs in the thick disk, halo, and globular clusters are identified in deep infrared imaging and spectroscopic fields by JWST, Euclid, and the Nancy Grace Roman Space Telescope.

Theme: Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

A Combined JWST, GRAVITY, and CRIRES+ study of Gl 229 B: binarity and atmospheric characterization

Jerry Xuan
Caltech
Friday 9:45am

Gl 229 B, the first T dwarf discovered, orbits a M1V star at 33 AU and has a dynamical mass of 71.4±0.6 MJup and Teff~850 K. From its bolometric luminosity, substellar evolutionary models predict masses 10σ lower than the dynamical mass, making Gl 229 B the touchstone of an emerging “over-massive” brown dwarf problem. Moreover, atmospheric retrievals using ground-based spectra have reported C/O>1 for the object, considerably higher than the C/O of Gl 229 A. We seek to unveil the mysteries behind Gl 229 B with a multi-instrument campaign. It is possible that Gl 229 “B” is an unresolved binary pair of brown dwarfs, which could explain its low luminosity and anomalous C/O measurements. To this end, we present VLTI/GRAVITY and CRIRES+ results that tentatively reveal Gl 229 B as a nearly equal-mass brown dwarf binary with a tight orbital separation of ~0.03 AU (~70 RJup). Armed with knowledge of the binary properties, we showcase atmospheric retrievals of JWST MIRI low-resolution spectrum (5-14 microns) for Gl 229 B, which contains absorption features from CO, CH_4, H_2O, and NH_3. We fit the JWST spectrum as both a single source and a binary source to compare the quality of fit. From the JWST spectrum, we also provide an updated bolometric luminosity and quantify the vertical mixing efficiency in the brown dwarfs' atmospheres by constraining the extent of carbon and nitrogen disequilibrium chemistry. Finally, we report revised C, O, and N elemental abundances for Gl 229 "B".

Theme: Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

Jupiter Mass Binary Objects - JuMBOs

Samuel Pearson
European Space Research and Technology Centre
Friday 10:00am

In recent observations of the Trapezium Cluster in the Orion Nebula with the JWST, we have discovered and characterised a sample of over 500 planetary-mass candidates with masses down to 0.6 Jupiter masses. In an unexpected twist we find that a significant population of these planetary-mass objects are in wide binaries. The binary fraction of stars and brown dwarfs is well known to decrease monotonically with decreasing mass such that the binary fraction for the planetary-mass regime is expected to approach zero. The existence of substantial population of Jupiter Mass Binary Objects (JuMBOs) raises serious questions of our understanding of both star and planet formation. In this talk I will present the discovery of these JuMBOs, the 500+ free-floating planetary-mass candidates, and discuss the implications for our understanding of star and planet formation.

Theme: Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

Exometeorology: Weather on Worlds Beyond Our Own

Johanna Vos
Trinity College Dublin
Friday 11:00am

Since the discovery of brown dwarfs 30 years ago, gaining an in-depth understanding of their atmospheres has emerged as a major challenge for the field. Concurrently, the complementary field of exoplanets has highlighted the similarities between brown dwarfs and the small but growing sample of directly-imaged exoplanets. Without a bright host star, isolated brown dwarfs serve as critical analogs for bona fide giant exoplanets. Studies to date have revealed the complex nature of brown dwarf and giant planet atmospheres. In particular, atmospheric phenomena such as condensate clouds, atmospheric dynamics and aurorae play a dominant role in shaping the appearance of extrasolar atmospheres. In this talk I will describe recent and ongoing efforts to reveal the physics of these three critical atmospheric phenomena as well as prospects for future work with next-generation facilities.

Theme: Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

A new window into cool dwarf's magnetospheres: radiation belts and beyond

Juan Bautista Climent
Universitat de València
Friday 11:30am

We present state-of-the-art very long baseline interferometry (VLBI) radio observations of the ultracool dwarf (UCD) LSR J1835+3259, which resolve for the first time ever the extended radio emission of this nearby UCD. The radio morphology is consistent with the presence of a steady radiation belt powered by synchrotron emission, and aurora, powered by the coherent electron cyclotron maser mechanism. This is the first time a radiation belt is found beyond our solar system. Those results show that, similar to the Jupiter case, radio emitting UCDs possess dipole-ordered magnetic fields with radiation belt-like morphologies and aurorae. In this talk, we will present the latest results on very-long baseline interferometry (VLBI) efforts on this magnetic structure akin to the Van Allen belts. We will also take a sneak peek into novel VLBI detections showcasing distinctive radio-emitting behaviors in various UCDs, and will discuss the potential implications of those behaviors on existing models of radio emission from UCDs.

Theme: Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

Explaining the Diversity of The Coldest Extrasolar Worlds

Genaro Suárez
American Museum of Natural History
Friday 11:45am

Substellar atmospheres exhibit a variety of chemical species and physical and chemical processes that determine their appearances. As substellar atmospheres cool, their chemistry becomes more complex. The JWST Cycle 1 program GO 2124 observed a sample of 12 of the coldest known extrasolar atmospheres of objects at the T/Y transition. With unprecedented precision using NIRSpec G395H spectra and MIRI long wavelength photometry, we present a detailed spectral sequence of the coldest brown dwarfs focusing on the diversity present in ultracool atmospheres. Particularly, we present: 1) prominent molecules and their state of chemical equilibrium/disequilibrium 2) the most complete SED of an extrasolar world and its retrieval and forward modeling analysis, 3) the detection and modeling of methane in emission in a substellar atmosphere indicative of auroral activity, 4) far/mid-infrared color-magnitude diagrams, and 4) progress on the retrieval and self-consistent modeling for the whole sample. Because of similarities between T/Y transition dwarfs and giant exoplanets, the observations and results presented here also allow us to constrain the aspects that may influence the appearance of exoplanets.

Theme: Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

Spatial Variations in Atmospheric Chemistry of the Coldest Brown Dwarf

Brittany Miles
University of Arizona
Friday 12:00pm

For two decades astronomers have been measuring weather on other worlds with the goal of understanding what atmospheric phenomena drive time-dependent brightness variations in brown dwarfs and gas giant exoplanets. Previous weather studies have been limited to broadband photometry or low resolution (R ~100) spectroscopy. In the era of JWST, precise time-resolved medium-resolution spectroscopy of the coldest brown dwarfs is finally possible, allowing the effects of chemistry, temperature, and condensates to be disentangled. WISE 0855 (280K) is the coldest known brown dwarf and the best analog for studying processes that also occur on gas giant planets within our Solar System. We present high SNR (80 – 100), medium resolution (R ~1000), time-series JWST/NIRSpec spectra of WISE 0855. Our observations span 11 hours with 15 minute pointings covering 2.87–5.27 microns. The dominant time-variable feature is carbon monoxide (CO) gas absorption, producing modulations in its band strength with peak-to-peak amplitudes of 8%. We discuss the changes in CO in the context of other expected disequilibrium species such as phosphine and carbon dioxide. Using atmospheric and structural models, we investigate the impact of water clouds based on observed water vapor features. Lastly, we discuss JWST's potential to measure similar features on other cold brown dwarfs and widely-separated gas giant exoplanets.

Theme: Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

Direct Imaging Spectroscopy of Substellar Companions with JWST

Kielan Hoch
Space Telescope Science Institute
Friday 12:15pm
JWST has opened the door to spectroscopy of directly imaged exoplanets beyond 3 microns, offering a new landscape for measuring their fundamental and atmospheric properties. Directly imaged exoplanets are Jupiter analogs that orbit at large separations (~10-100 AU) from their host stars. These planets, with masses of ~2-14MJup and temperatures of ~500-2000 K, remain a mystery for planet formation models—core accretion and gravitational instability. Observations that probe elemental abundances in these companions can shed light on their formation. We present results from cycle 1 programs that have pioneered the use of JWST's NIRSpec IFU to obtain spectra of substellar companions close to sunlike stars. For HD 19467 B, NIRSpec spectra show detections of CO, CO2, CH4, and H2O. We forward model the R~2,700 spectra using custom PHOENIX atmospheric model grids to constrain the abundances, the C/O ratio, and non-equilibrium chemistry. For the multi planet system YSES-1, we have obtained one of the most comprehensive datasets of a multi-planet system with spectral coverage from 1-12 microns using NIRSpec and MIRI. The spectra allow direct spectral comparison of sibling planets in unprecedented detail. These spectra show a direct detection of silicate clouds in the 6 MJup exoplanet YSES-1 c. Ongoing atmospheric modeling will better constrain non-equilibrium chemistry and cloud composition to increase our understanding of substellar atmospheres and formation.

Theme: Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

Posters

Monday & Tuesday Posters

1: The connection between exoplanet atmospheres and solar EUV and Lyman-alpha radiation

Jeffrey L. Linsky
JILA/University of Colorado

Stellar extreme Ultraviolet (EUV) radiation (10-91.2 nm) is primarily responsible for driving hydrodynamic mass loss from their exoplanets, which determines whether an exoplanet can retain its atmosphere and water. Stellar Lyman-alpha radiation is primarily responsible for photo-dissociating water and methane in exoplanet atmospheres, and therefore plays a major role in determining the chemistry in their upper atmospheres. Both the EUV spectral energy distribution and the Lyman-alpha flux cannot be directly observed because of interstellar

hydrogen absorption, and thus must be estimated or reconstructed from the observed data or theory. This talk will describe the various techniques for estimating or reconstructing these intrinsic fluxes that are based on solar spectra or are tested against solar spectra. I will analyze the applicability and limitations of these techniques for solar-type stars and M dwarfs that host exoplanets.

Theme(s): The Sun and Cool Stars in the Time Domain

2: Search for extragalactic exoplanets inner the Milky Way

N. Souza (1); D. Souto (1); H. Perottoni (2)
Federal University of Sergipe, Aracaju, Brazil; National Labboratory for Astrophysics, Itajubá, Brazil

The discovery of exoplanets beyond our solar system in recent decades has led to searches for the origins of these other worlds. In this study, we investigate the possibility of exoplanets originating from beyond our galaxy, but without the need for observations outside the Milky Way, considering the potential for exoplanet-hosting stars to have been accreted through the last major merger event with the dwarf galaxy Gaia-Enceladus, 10 billion years ago. Utilizing data from the GAIA DR3 catalog and multi-region spectroscopic catalogs such as APOGEE, SEGUE, RAVE, LAMOST, and GALAH, crossmatch were performed to identify halo stars that may have been affected by Gaia-Enceladus. This merger event is considered a possible mechanism for the introduction of extragalactic interstellar material into the Milky Way's disk. By calculating the orbital parameters of the identified stars, it is possible to analyze their kinematics to determine if they exhibit characteristics consistent with an origin in the galactic halo. Previous results suggest the presence of a population whose kinematics indicate a possible extragalactic origin, raising the possibility of the existence of exoplanets originating beyond the Milky Way. This study contributes to a deeper understanding of the formation and evolution of planetary systems on cosmic scales.

Theme(s): Milky Way-scale Science and Big Data, Cool Stars as Stellar Systems

3: Episodic Mass Loss: the Curious Case of Betelgeuse

Andrea K. Dupree (1); Thomas Calderwood (2); Thomas Granzer (3); Morgan MacLeod (1); Lynn D. Matthews (4); Klaus Strassmeier (3); and Michael Weber (3)
Center for Astrophysics | Harvard & Smithsonian, Cambridge MA USA; American Association of Variable Star Observers (AAVSO), Cambridge MA USA; Leibniz-Institut für Astrophysik Potsdam (AIP), Germany; Massachusetts Institute of Technology, Haystack Observatory, Westford MA USA

The red supergiant Betelgeuse (Alpha Ori, M2 I) experienced a substantial Surface Mass Ejection in 2019 caused by the confluence of the pulsation period, a shock wave, and possibly a convective plume. This event cooled the photosphere, traveled through the chromosphere, and led to dust that dimmed the star: The Great Dimming. In the 5 subsequent years, the star has

not fully recovered and its well known 400-day fundamental pulsation has not yet returned. We present hydrodynamic modeling, recent AAVSO photometry , spatially resolved observations with VLA and ALMA, optical spectroscopy (STELLA and TRES) from the ground and space including HST/STIS spatially resolved ultraviolet spectra in order to assess the event and the star's recovery.

Theme(s): New Insights into Star Formation and Evolution, The Sun and Cool Stars in the Time Domain

4: How stable are solar-type cycles over half a century? Chromospheric S-indices Mt. Wilson vs. TIGRE

Klaus-Peter Schröder (1); Jürgen Schmitt (2); Marco Mittag (2)
Departamento de Astronomia, Universidad de Guanajuato, Mexico; Hamburger Sternwarte, University of Hamburg, Germany

Since autumn 2013, the robotic 1.2m telescope TIGRE (formerly the Hamburg Robotic Telescope) is operating in Guanajuato (Mexico, and see poster by Gonzalez et al.). Regularly using the same calibration stars for S-indices as did the Mount Wilson project (see Baliunas et al. 1995), our R=20,000 HEROS echelle spectra have provided a decade of chromospheric activity monitoring of the same ca. 100 solar-type stars, including a smaller number with pronounced cycles (see Schröder et al. 2013) of periods of o(10yrs), which were already observed at Mount Wilson since the 1970ies. Hence, on a timescale of half a century, we can now use those same stars, first shown by Olin C. Wilson and his group to perform solar-type activity cycles, to probe the stability of these cycles. This is motivated by the solar cycle variability, which is evident, when comparing the last two, relatively weak maxima monitored by TIGRE, with the Mount Wilson data from the 1970ies and 1980ies. Hence, we here show that this is not a singular behavior. Strong cycles seem to be less variable, while weaker cycles like the solar are natural to change between stronger and weaker performance. In the case of the Sun this behavior is consistent with an o(century)-period as of the semi-regular Gleissberg cycle, as well as with the occurrence of grand-minima.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

5: Rotation Periods of Candidate Single Ultracool Dwarfs in TESS

S. Lambier (1); S. Metchev (1); D. Wolfe (1); P. Miles-Páez (2); L. Moranta (3, 4); J. Martinovic (1); J. Hales (1)
Western University, London, ON, Canada; Centro de Astrobiología, CSIC-INTA, Spain; Planétarium Rio Tinto Alcan, Montréal, QC, Canada; Institute for Research on Exoplanets, Montréal, QC, Canada

Recent studies suggest that the angular momentum evolution of ultracool dwarfs differs from the well-known spin-down evolution of hotter stars. Characterizing the distribution rotation periods of ultracool dwarfs in the solar neighbourhood can help elucidate this evolutionary pathway just above, at, and below the hydrogen burning limit. Here, we present the results of our study focusing on determining rotation periods for our initial catalogue of \sim 400 candidate single ultracool dwarfs. We conducted our analysis in uncrowded TESS fields, utilizing SPOC PDCSAP data. To achieve this, we employed Lomb-Scargle Periodograms to provide a first estimate of the period, then refined them with a Gaussian Process approach. We further confirm that the periodicity observed is not due to contamination using TESS-Localize. In our comparison with rotation periods reported in the literature, we found consistent results, while also uncovering new periods ranging from 2 hours to 2.5 days. Future research aims to address ultracool dwarfs in TESS crowded fields, with the end goal of a complete analysis of ultracool dwarf rotations within the TESS flux limits.

Theme(s): The Sun and Cool Stars in the Time Domain, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

6: The Starchive: The User-centered Stellar Database we all Need

A. Tanner (1); D. Muna (2)
Mississippi State University; NASA

With so much data being produced by the stellar and exoplanet community and the continued need for target list vetting for NASA missions like HWO and Roman, we created the Starchive - an open access stellar archive. The database includes stellar properties, photometry, high-contrast imaging, spectra, and time series. It contains over 40,000 stars, white dwarfs, and brown dwarfs. This is accompanied by 122k references, 192k photometry and flux values and 1.2 million stellar, disk and planet properties. To facilitate accessing this diverse database, there is a web application with multiple functions. Users can do a filtered search, an object or list search, a radius search, and a reference search. If searching on one star, the user is sent to a page with the stellar parameters, finder charts, an Aladdin image, an airmass chart, an SED, and a multiplicity tree. If the search results in multiple stars, users are given a dynamic, downloadable table and a suite of plotting tools. The website also allows users to upload data into the database directly via a webform or formatted .csv file. The community will be encouraged to upload data to the database to increase citations and fulfill data sharing grant requirements efficiently. This type of a user- or science-centered database (as opposed to catalog-centered) is intended to increase access to scientific data in the spirit of the FAIR standards with an emphasis on the “findable” and “accessible” aspects of this principle.

Theme(s): Milky Way-scale Science and Big Data, Cool Stars as Stellar Systems

7: APPLE: An Evolution Code for Modeling Giant Planets

Ankan Sur; Yubo Su; Roberto Tejada Arevalo; Yixian Chen; Adam Burrows
Princeton University

We introduce APPLE, a novel planetary evolution code designed specifically for the study of giant exoplanet and Jovian planet evolution in the era of Galileo, Juno, and Cassini. With APPLE, state-of-the-art equations of state for hydrogen, helium, ice, and rock are integrated with advanced features to treat ice/rock cores and metals in the gaseous envelope; models for helium rain and hydrogen/helium immiscibility; detailed atmosphere boundary tables that also provide self-consistent albedos and spectra; and options to address envelope metal gradients and stably-stratified regions. Our hope is that these purpose-built features of APPLE will help catalyze the development of the next generation of giant exoplanet and Jovian planet evolutionary models

Theme(s): New Insights into Star Formation and Evolution, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

8: A Substellar Cooling Age for the \beta Pictoris Moving Group

Trent Dupuy (1); Michael Liu (2); Will Best (3); Beth Biller (1); Kaitlin Kratter (4) ; Adam Kraus (3); Andrew Mann (5); Evgenya Shkolnik (6); Katelyn Allers (7)
University of Edinburgh; University of Hawai`i at Manoa; University of Texas at Austin; University of Arizona; University of North Carolina; Arizona State University; Bucknell University

Age is notoriously one of the most difficult fundamental properties to determine accurately. One problem is that relatively few "clocks" are available: astrophysical objects with observable properties that evolve significantly enough to be used for age-dating. Substellar objects have no evolutionary phase where their luminosity is stable, making them potentially very effective clocks across all ages. However, because their luminosity also fundamentally depends on their mass, substellar cooling ages can only be calibrated with directly measured masses of brown dwarfs. Progress has been very slow, as precious few binaries with feasibly short orbital periods are known in stellar associations with precise, independent age constraints. We present dynamical masses for the planet-hosting binary system 2MASS J0249-05AB, which is a member of the \beta Pic moving group, from over a decade of our Keck adaptive optics orbit monitoring. Both components straddle the substellar boundary within their ~8% mass uncertainties, and their corresponding model-derived cooling ages (~15% uncertainties) are consistent with the well-established age of the \beta Pic moving group (24\pm3 Myr). This is the youngest age at which such a test of evolutionary models has been done, and it is somewhat at odds with the only other test to date, where the model cooling ages of two ~40-Jupiter-mass brown dwarfs were ~60% older than expected from their membership in the Argus moving group (~45 Myr).

Theme(s): Cool Stars as Stellar Systems, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

9: Observed Quasi-periodic Pulsations in Stellar Flares of a Highly Active Low Mass Star

Teresa Monsue (1,2); Joshua Schlieder (1); Laura D. Vega (1,4); Rishi R. Paudel (1,3); Thomas Barclay (1); Jordan Ealy (4); Emily A. Gilbert (5); Michele L. Silverstein (6); Allison Youngblood (1) and Elisa V. Quintana (1)
NASA Goddard Space Flight Center, Greenbelt, MD 20771; The Catholic University of America, Washington, DC 20064; University of Maryland, Baltimore County, Baltimore, MD 21250; University of Maryland, College Park, MD 20742; NASA Jet Propulsion Laboratory, Pasadena, CA 91109; Naval Research Laboratory, Washington D.C. 20375;

Stellar atmospheres encompass an abundance of waves and oscillations. This includes those associated with flares. Oscillatory and pulsating signatures, commonly known as quasi-periodic pulsations (QPPs), are observed at many wavelengths during both solar and stellar flares. These oscillatory phenomena travel on magnetic field lines in the star's atmosphere and can provide insight into the astrophysical processes of flares. We present a study of flare oscillations in a nearby, active M3 dwarf star, EV Lacertae. We make a comparison of QPP observations with near-UV high cadence data (~1 sec) from NASA's Swift mission and TESS 20-second cadence optical data. We measure QPP properties and place constraints on the fundamental processes driving flares at different layers of the stellar atmosphere. We present preliminary results of our study.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

10: Red giant magnetism probed by 3D MHD simulations

L. Amard (1); A.S. Brun (1); A. Palacios (2)
Département d'Astrophysique/AIM, CEA/IRFU, CNRS/INSU, Univ. Paris-Saclay & Univ. de Paris F-91191 Gif-sur-Yvette, France; LUPM, Université de Montpellier, Place Eugène Bataillon, 34095 Montpellier, France

The magnetism of red giant stars is still poorly understood. On one hand, close to the core, asteroseismology revealed magnetic field up to several hundred thousand Gauss, on the other hand, spectropolarimetric observations of the surface magnetic field of the red giant Pollux have revealed a global field of the order of a Gauss. Using the anelastic code ASH, we computed the first set of 3D MHD non linear simulations to understand the dynamo processes at work within the convective envelope of a red giant. I will present the results of these simulations and compare them to the most recent observational work. In particular, we find that observations can be explained with a small scale dynamo associated to small scale convective motions.

Theme(s): New Insights into Star Formation and Evolution, The Sun and Cool Stars in the Time Domain

11: Planet Induced Stellar Flares from the TESS Mission

Nathan Whitsett, Tansu Daylan
Washington University in St. Louis; McDonnell Center for the Space Sciences

The detection of exoplanetary magnetic fields is an essential goal for the continued characterization and contextualization of exoplanets. In particular, an orbiting exoplanet with a magnetosphere can induce flares on its host via magnetic reconnection. We conduct a comprehensive search for induced flares in multi-cadence TESS data in the first five years of the mission, using Bayesian evidence to vet underresolved flare candidates. Specifically, we estimate the flare frequency distribution by cataloging flares from all confirmed or candidate planet hosts, with particular focus on M dwarf hosts. We discuss candidate targets potentially manifesting star-planet interactions based on elevated flaring activity correlated with arguments of periastron and Alfven-surface crossings, and compare results with simulated data. Continued long-term monitoring of flaring stars by TESS and the upcoming ULTRASAT mission will yield complementary tests for the accumulating evidence for the existence of planetary magnetospheres based on radio observations of the Low-Frequency Array (LOFAR) and UV observations of the Hubble Space Telescope (HST).

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

12: Dating Cool Main-Sequence Stars with the Activity-Age Relation

Yaguang Li (1); Tanda Li (2)
University of Hawaii; Beijing Normal University

Investigating the relationship between age and activity in cool stars was faced with two main challenges. The first challenge is the measurement of activity indices across a wide range of stellar parameters, which demands extended periods of observation for numerous stars. All-sky surveys such as LAMOST facilitate addressing this challenge by providing activity indices for millions of stars. The second challenge is the accurate estimation of stellar ages, especially for K-type stars. Recent studies have shown that kinematic velocity dispersion can serve as a reliable indicator of age for stars in the solar neighborhood. In this work, we have mapped the relationship between kinematic ages and LAMOST measured activity indices (log R’HK), for stars between 6,000 K and 4,000 K. We found that K-type stars exhibit a relationship that is similar to those found in G- and F-type stars, but with a generally higher activity level. Using the ages derived from activity levels, we have observed a disruption in the spin-down process in older main-sequence stars, adding another piece of evidence to the theory of weakened magnetic braking.

Theme(s): New Insights into Star Formation and Evolution, Cool Stars as Stellar Systems

13: The Sun as a spatially resolved star - Centre-to-limb investigations of the quiet Sun

M. Ellwarth; A. Reiners
Institut für Astrophysik und Geophysik, Göttingen, Germany

Investigating stellar systems is constantly challenged by the intrinsic need to disentangle stellar features and planetary signals. Varying stellar disc positions can be covered while the planet orbits the host star. Accurate models for stellar atmospheres are crucial to attribute signals to the respective celestial bodies correctly. The Sun, the only spatially resolvable star, is an ideal subject to receive an atmospheric blueprint for solar-like stars. We investigated the limb-dependent convective blueshift, considering line depth and formation temperature. Our analysis focuses on the convective centre-to-limb variations of the quiet Sun, employing our spatially resolved IAG solar atlas. We investigate the Doppler shifts of over 1000 Fe I lines from the disc centre towards the limb (mu = 1.0 - 0.2). Convective line shifts generally show a decreasing blueshift as the formation temperatures decrease. The different observation positions on the solar disc display a velocity trend with a less pronounced convective blueshift towards the limb. In addition, our investigation revealed a wavelength dependency in the convective Doppler velocities, exhibiting a variance of over ~200m/s. Furthermore, we take a look into the bisectors of hundreds of Fe I lines to investigate their behaviour considering their formation height.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

14: Apache Point Observatory follow-up of astrometrically selected exoplanet host candidates

A. Peck (1); E. Nielsen (1); R. De Rosa (2); Z. Wahhaj (2); W. Roberson (1); H. Gallamore (1); J. Klusmeyer (1); B. Macintosh (3); A. Smith (1)
New Mexico State University, Las Cruces, NM, United States; European Souther Observatory, Cerro Paranal, Chile; University of California Santa Cruz, Santa Cruz, CA, United States

Accelerating stars potentially host planets. If they are young, those planets could be directly imageable. By combiningGaia and Hipparcos measurements, we have identified stars with accelerations consistent with substellar companions at intermediate separations (5-20AU) but also unresolved short-period stellar binaries. We use spectra taken with the echelle spectrograph, ARCES, on the 3.5-meter telescope at Apache Point Observatory to determine each star’s suitability for direct imaging. We use ARCES data to conduct radial velocity monitoring of the sample to screen for stellar binaries. Using a Bayesian approach, we derive ages from rotation rates extracted from TESS light curves and from R’HK and lithium equivalent widths measured from ARCES spectra. Screening our sample for stellar binaries and identifying the youngest stars are key steps in generating a prioritized list of targets for direct imaging and increasing the number of directly imaged exoplanets. We present preliminary results from this ongoing survey.

Theme(s): Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

15: Exploring the Fundamental Limit of Star Formation: Free-Floating Planetary Mass Objects in NGC 2024

M. De Furio (1); M.R. Meyer (2); J. Leisenring (3); T. Greene (4); K. Hodapp (5); D. Johnstone (6,7); M. Rieke (3); M. Robberto (8, 9); T. Roellig (4)
The University of Texas at Austin, Austin, TX, USA; University of Michigan, Ann Arbor, MI, USA; Steward Observatory, University of Arizona, Tucson, AZ, USA; NASA Ames Research Center, Moffett Field, CA, USA; University of Hawaii, Institute for Astronomy, Hilo, HI, USA; NRC Herzberg Astronomy and Astrophysics, Victoria, BC, Canada; University of Victoria, Victoria, BC, Canada; Space Telescope Science Institute, Baltimore, MD, USA; Johns Hopkins University, Baltimore, MD, USA

Free floating planetary mass objects are expected to form directly through turbulent fragmentation of molecular cloud cores down to masses of \sim 1-10 M_{J}. These objects represent the fundamental low mass limit of the star formation process and are necessary to probe star formation theory and characterize the initial mass function. They may, however, also form originally as planets within the disk of a host star and then be dynamically ejected into the surrounding star-forming region. We present the results of a deep imaging survey with JWST/NIRCam (GTO: 1190, PI: M.R. Meyer) within the core of NGC 2024, a young (< 1 Myr) embedded star-forming region, across 0.7 - 5 microns using eight separate filters, each totaling two hours in exposure time. Using a novel automated routine to find faint point sources, we have identified dozens of candidate planetary mass objects with estimated masses \geq 1 M_{J} from spectral energy distribution fitting of the photometry using the ATMO2020 models. We present our characterization of the initial mass function down to the completeness limits of our survey and discuss the implications of our results in the context of various star and planet formation models. We also discuss the detection of candidate low mass brown dwarf and planetary mass binaries in the context of the star formation process and previous multiplicity surveys.

Theme(s): Cool Stars as Stellar Systems

16: Coronal photons, flares, and particles: stellar EUV spectroscopy with ESCAPE

Allison Youngblood (1); Kevin France (2); James Mason (3); Brian Fleming (2); and the ESCAPE Science Team
NASA Goddard Space Flight Center, Greenbelt, USA; Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder, USA; Applied Physics Laboratory, Johns Hopkins University, Laurel, USA

The magnetically heated regions of a cool star’s atmosphere are complex and dynamic, unleashing energy via photons and particles into interplanetary space. In Heliophysics, Earth, and Solar System sciences, extreme-ultraviolet (EUV; 100-912 Å) observations of the Sun are fundamental for understanding solar activity, eruptions, and solar impacts on the Earth and other solar system bodies. Similarly, a complete picture of stellar magnetic activity and its impacts on exoplanet atmospheres requires access to the EUV spectral region. EUV astrophysics observations are challenging due to the interstellar medium, requiring sensitive new instruments such as the Extreme-ultraviolet Stellar Characterization for Atmospheric Physics and Evolution

(ESCAPE) mission concept to be submitted to the upcoming NASA Astrophysics Small Explorer call. ESCAPE will provide the first comprehensive study of the stellar EUV and coronal mass ejection (CME) environments of nearby cools stars. ESCAPE simultaneously measures EUV and FUV irradiance, flare rates, and the properties of CMEs via time-resolved 80-1650 Å spectroscopy of over 220 FGKM stars. ESCAPE employs a grazing incidence telescope feeding multiple diffraction gratings and a photon-counting detector. A prototype of the ESCAPE telescope will fly on NASA's MANTIS cubesat in 2027.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

17: Solar neighborhood activity scatter quantified with magnetic activity in co-eval wide binaries

D. Dsouza(1,2); N. Ilić (1); K. Poppenhäger(1)
Leibniz-Institut für Astrophysik Potsdam, Germany ; University of Potsdam, Germany

The magnetic activity of stars in the unsaturated regime is connected to the stellar age, however, the scatter in variability in activity of cool stars in Gyr ages are not well understood. We estimate this scatter by using a sample of 34 same spectral type wide binaries. Archival X-ray data from Chandra and XMM-Newton is used to find the X-ray luminosity (L_X), an indicator of magnetic activity in the stellar Corona. The difference in L_X between the coeval components of the binary gives us the scatter observed in co-eval stars. In the solar neighborhood, we find the scatter in randomly paired same-spectral-type stars within 14pc deviate by more than one sigma when compared to co-eval stars in a wide binary. In addition, despite the low scatter, we also observe a bi-modality in the scatter for M dwarfs in the co-eval sample. As the activity-rotation relations and gyrochronology continue to be calibrated for field stars, volume limited X-ray surveys of stars can also help determine the degree of deviation from coeval behavior in the solar neighbourhood without the need to determine precise ages.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

18: Machine Learning Classification of the Flares in HARPS-N Solar Spectra

Laura Flagg (1); Nicole Hao (1); Ray Jayawardhana (2)
Cornell University; Johns Hopkins University

Studying the wavelength dependence of flares is important, because it gives us insight into flare structure and because that wavelength dependence leaves an imprint on transiting exoplanet atmosphere observations. Thus, being able to detect and characterize the wavelength dependence of flares is crucial for studying both stars and exoplanets. However, spectra of flares are hard to acquire, because the timing of flares is unpredictable. We used the Solar spectra taken with HARPS-N to study Solar flares. We labeled each spectrum as “no flare,” “weak flare,” or “strong flare” by matching the time of the observation with the RHESSI X-Ray Solar flare database. We then trained a machine learning algorithm (support vector machine) to

classify the Solar spectra into those categories. Despite the fact that none of these flares can be seen by eye in the optical spectra, our algorithm is accurate >60% of the time, a significant improvement upon a blind classification, which would be accurate 1/3 of the time. This algorithm can be extended to other Solar-type to allow us to detect weaker flares in their spectra.

Theme(s): The Sun and Cool Stars in the Time Domain

19: X-ray emission from pre-main sequence stars with multipolar magnetic fields

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Stars on the pre-main sequence (PMS) are highly X-ray luminous. Their corona can support X-ray emitting plasma along magnetic field loops on scales of a couple of stellar radii. X-ray observations of PMS stars reveal a decrease of X-ray luminosity with age after ~7 Myr, with stars on Henyey tracks having lower fractional X-ray luminosities (L_{\rm{X}}/L_*) than those on Hayashi tracks. Separate observations find that stars typically start the PMS with simple magnetic fields dominated by dipole and octupole components. Their magnetic fields increase in complexity as they evolve from the Hayashi track to the Henyey track. We investigate the connection of these observations by analysing the impact of a PMS star's large-scale magnetic field topology on the X-ray emission from the corona. We construct model coronae assuming axisymmetric magnetic fields, either with pure multipole fields or with dipole and octupole components. The coronal extent of the X-ray emitting plasma and the subsequent X-ray luminosity are determined using pressure balance arguments. We find that as magnetic field topologies become more complex (by increasing the pure multiple degree or the dominance of the octupole in a dipole-octupole field), the X-ray luminosity decreases, dropping by over an order of magnitude. Our findings reinforce that increasing the magnetic field complexity of PMS stars contributes to reducing their X-ray luminosity.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

20: Age-Dating the Pisces-Eridanus Stellar Stream: From Binary Star \tau^1 Aqr and Cool Star Members

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We study the nearby young (~100 Myr) moving group known as the Pisces-Eridanus Stellar Stream (Psc-Eri), which contains rapidly-rotating low-mass stars, a massive white dwarf (WD), and a bright double-lined spectroscopic and interferometric binary. \tau^1 Aqr has a B9V-type primary star and is nearing the group's main sequence turnoff, making the stars' characteristics especially sensitive to the age of Psc-Eri. For this reason, we analyze spectroscopic and interferometric observations to precisely measure the masses of the stars and age date Psc-Eri.

Orbital modeling of the binary data reveals a period of P = 28.0755 days, and masses M_1 = 2.59 M_\odot and M_2 = 1.21 M_\odot. Analysis of the stars' characteristics will reveal the precise age of \tau^1 Aqr, and of Psc-Eri. We will compare the cooler stars of Psc-Eri with the Pleiades in the gyrochronology and color-magnitude diagrams. Determining the age more precisely will help reveal the initial mass of the massive WD member of this group, providing more insight to the high-mass end of the WD initial-final mass relation (IFMR).

Theme(s): New Insights into Star Formation and Evolution, Milky Way-scale Science and Big Data

21: Twin M Dwarfs Appear Both Fraternal and Identical in Activity and Rotation

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M dwarfs that host exoplanets -- such as TRAPPIST-1 and Proxima Centauri -- can demonstrate remarkably strong stellar activity, with a variety of potentially significant impacts on the orbiting planets and their atmospheres. Understanding the evolution of a planet's habitability therefore depends on reconstructing the evolution of its host star activity. However, the complex nature of M dwarfs has thus far prevented robust and precise determinations of this activity evolution. To this end, we have assessed the general predictability of stellar activity by investigating a sample of 36 M dwarf wide binaries with identical `twin' components. Key subsets have been observed with several campaigns to obtain rotation periods, multi-epoch H-alpha equivalent widths, X-ray luminosities, and long-term optical photometry. We also employ time series radial velocities and speckle interferometry to check for unresolved companions. Here we show results for the full sample, where many twin stars have surprisingly congruent measurements, in contrast to four notable systems demonstrating consistent differences in activity and/or rotation. This effort has been supported by the NSF through grant AST-2108373, NASA through Chandra grant G01-22-13B, NOIRLab through proposal 2023A-549259, and via observations made possible by the SMARTS Consortium.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

22: Young Star Spot Structure & Impact on RVs Via Time-Domain High-Resolution Spectroscopy

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To characterize the spot-induced variability of T Tauri Stars (TTSs) and to facilitate the discovery of the planets orbiting them, we have collected hundreds of high-resolution optical and NIR spectra in our Young Exoplanets Spectroscopic Survey over two decades. By analyzing Teff sensitive lines, we used M-dwarfs with interferometrically determined Teff to formulate an empirical equivalent width ratio (EWR)-Teff relationship for Teff values from 3400 to 5000 K to shed light on stellar activity nuances. Our comparative analysis of spectral models reveals broad agreement but also highlights significant disparities, indicating a pressing need for refined cool star atmospheric modeling and more accurate determination of physical parameters from observations. Our findings reveal temperature variations >150 K in individual TTSs, confirming substantial stellar activity beyond measurement scatter. Furthermore, the correlation of average surface magnetic field strengths with Teff variations stresses the dynamic interplay between magnetic field strengths and stellar surface features. Notably, a quarter-phase delay between EWR and RV phase curves signals spot-driven RV modulation. CI Tau's zero phase delay hints at more intricate dynamics, possibly a planetary origin. This study, blending observations and models, offers vital contributions to the time-domain exploration of young stars' activity cycles and magnetic field dynamics during the critical phase of planet formation.

Theme(s): The Sun and Cool Stars in the Time Domain

23: Parameters of Cool Exoplanet Host Stars on the Habitable Worlds Observatory Provisional Target List

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Yale University; University of Michigan

To characterize the exoplanets a star may host, accurate stellar parameters must be well-determined. Ahead of the future Habitable Worlds Observatory (HWO) mission, the field needs to conduct a survey of the provisional target stars to find the most likely to host detectable Earth-like exoplanets; determining stellar parameters for the mission's targets is crucial to more accurate and efficient analysis, and may inform the technical requirements of the mission itself. We analyze data for several of these targets to provide updated parameters. In this study, we use new long-baseline optical interferometric data from the CHARA Array with the MIRC-X and MYSTIC beam combiners and extreme precision spectroscopic data from the Lowell Discovery Telescope with EXPRES to improve constraints on the stellar parameters of a small group of provisional targets in a pilot study. We discuss these stellar parameters, including radius, mass, log g, and vsini, and their implications for possible exoplanet systems around these stars.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

24: On the source of the Fe Kalpha emission in T Tauri Stars

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T Tauri Stars (TTSs) are magnetically active stars that accrete matter from the inner border of the surrounding accretion disc; plasma gets trapped into the large scale magnetic structures and falls onto the star, heating the surface through the so-called accretion shocks. The X-ray spectra of the TTSs show prominent Fe~Kalpha fluorescence emission at 6.4~keV that cannot be explained in a pure accretion scenario since its excitation requires significantly more energy than the maximum available through the well constrained free-fall velocity. Neither, it can be produced by the hot coronal plasma. TTSs display all signs of magnetic activity and magnetic reconnection events are expected to occur frequently. In these events, electrons may get accelerated to relativistic speeds and their interaction with the environmental matter may result in Fe~Kalpha emission. In this work, we present the results of our simulations to evaluate the X-ray radiative output from the propagation of high-energy electrons in the TTS environment. A set of conditions representing the environment of the TTSs where these showers may impinge has been taken into account to generate a grid of models that can aid to the interpretation of the data. The simulations show that the electron beams produce a hot spot at the point of impact; strong Fe~Kalpha emission and X-ray continuum radiation are produced by the spot. We show that this emission is compatible with the X-ray spectrum of RY Tau during flares.

Theme(s): New Insights into Star Formation and Evolution, The Sun and Cool Stars in the Time Domain

25: The Gaia Ultracool Dwarf Sample – V: The Ultracool Dwarf Companion catalogue

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We present the Ultracool Dwarf Companion catalogue of 278 multiple systems, each with at least one spectroscopically confirmed Ultracool Dwarf, within a 100 pc volume-limited sample. This catalogue is compiled using the Gaia Catalogue of Nearby Stars for stellar primaries and the Gaia Ultracool Dwarf Sample for low-mass companions. The catalogue includes 241 doubles, 33 triples, and 4 higher-order systems established from positional, proper motion, and parallax constraints. This catalogue seeks to identify probable benchmark systems within 100 pc to obtain model-independent astrophysical parameters of UCDs. We calculate the probabilities of chance alignments to evaluate the physical nature of each system. We include astrometric and photometric data from Gaia Data Release 3 and the Two Micron All Sky Survey. We identify potential unseen companions using a combination of the Renormalised Unit Weight Error, Image Parameter Determination statistics, Non-Single Star solutions, and photometric blending as provided by Gaia. Our catalogue includes 17 White - Ultracool Dwarf systems, whose ages are determined using cooling models. We also use the Gaia FLAME results and the

BANYAN Σ procedures to age 40 and 34 systems respectively, and derive mass estimates from evolutionary models.

Theme(s): Cool Stars as Stellar Systems, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

26: The SIMPLE Archive: A database and website of low mass stars, brown dwarfs, and exoplanets

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We present the SIMPLE Archive of low mass stars, brown dwarfs, and directly-imaged exoplanets. The SIMPLE Archive currently contains the astrometry, photometry, and spectra for over 3,000 sources. The goal of SIMPLE is to develop a community-driven archive where many individuals can collaboratively contribute to the knowledge base of these objects using a GitHub workflow. SIMPLE can be searched via a website, https://simple-bd-archive.org/, or be downloaded and interacted with as a database. We welcome more contributors to join us as we build and populate this community tool. The SIMPLE Archive is actively being developed on GitHub at https://github.com/SIMPLE-AstroDB/SIMPLE-db. We are also building in parallel a generic, template version of this tool to be used for other types of astronomical objects: https://github.com/astrodbtoolkit/astrotemplate-db.

Theme(s): Milky Way-scale Science and Big Data, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

27: Longest Lightcurve of an Extrasolar World: Latitude-dependent Waves and Modulations in Luhman 16 B

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We present the longest photometric monitoring with TESS of up to 1200-hours of the brown-dwarf binaries Luhman 16AB, documenting ±5% variability for periods <10-hours. We show that short-period rotational modulation around 5-hour (k=1) and 2.5-hour (k=2) dominate the variability, where the planetary-scale waves model of k=1 and k=2 waves fit the lightcurve extremely well. We explain the difference in the narrowed range of k=2 periods compared to k=1 periods using models of zonal banding in Solar System giants (Jupiter and Saturn) and suggest

that this difference arises from higher wind speed distribution at low latitudes compared to mid-to-high latitudes. Lastly, we show that Luhman 16 AB exhibits long-period ±5% variability with periods up to 100-hour - potentially coming from polar regions in the atmospheres? Our results are consistent with past GCMs, demonstrating that zonal-banding, latitude-dependent waves, and slowly varying atmospheric features are present in Luhman 16 AB, and we will discuss the implication of this result in the viewpoint of equatorial-vs-polar circulation difference on ultracool atmospheres.

Theme(s): Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

28: Discovery of Brown Dwarf Members in the Globular Cluster NGC 6397

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We present the first discovery of brown dwarfs in a globular cluster with confirmed cluster membership. We identified three substellar members with effective temperatures between 1300 and 1800 K in the JWST NIRCam images of the globular cluster NGC 6397. The membership of these objects was verified with proper motion selection, using archival HST data. We employed a new set of model isochrones with non-solar abundances, computed across the stellar/substellar transition, to confirm that the discovered objects have masses well below the hydrogen-burning limit. The long-term cooling of brown dwarfs allows the ages of parent populations to be estimated from the observed luminosity function of the substellar sequence. Using this technique, we calculated the age of NGC 6397 as 13.4 ± 3.3 Gyr. Based on the cluster age determined by us and other estimates in the literature, we conclude that the newly discovered substellar members of NGC 6397 are likely the oldest known brown dwarfs with reliable age measurements.

Theme(s): New Insights into Star Formation and Evolution, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

29: Discovery of the first halo white dwarf + L subdwarf wide binary

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We present the discovery of the first halo white dwarf + L subdwarf wide binary in Gaia DR3. It is a gravitationally bound system with a projected separation of 1375 au. The system has a total space velocity of 405 km/s, which suggests it is a member of the Galactic halo. The secondary is an L subdwarfs with metallicity of [M/H] = -0.82+/-0.09 and Teff = 2290+/-30 K according to atmospheric model fitting to its optical to NIR spectrum. The L subdwarf is just above the stellar substellar boundary, and is the lowest mass halo star. Such a lowest mass star has low-rate hydrogen fusion, thus its initial thermal energy has significant contribution to its luminosity. Its temperature has dropped significantly in the last 10 Gyr, due to the dissipation of its initial thermal energy. The primary is a cool DC WD with a cooling time of 8.9 Gyr and a total age of 10.7+/-0.7 Gyr according to white dwarf model fitting. With age constrain from the WD companion, the secondary companion becomes the first age benchmark L subdwarf of the Galactic halo.

Theme(s): Cool Stars as Stellar Systems

30: A hot Jupiter progenitor on a super-eccentric, retrograde orbit

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We present the discovery of a transiting giant exoplanet on a long-period (P = 165 days), super-eccentric (e=0.94), and retrograde (\lambda = 160°) orbit around a main sequence star in a hierarchical triple system. Using measurements from a suite of ground-based facilities, including a partial transit recovery via diffuser-assisted photometry with ARCTIC and radial velocity measurements with the NEID, HPF, and HARPS-N spectrographs, we confirm the planetary origin of a single transit detected by TESS and we tightly constrain the physical and orbital properties of the system. The orbit is measured to be more eccentric than that of any other transiting exoplanet. In-transit NEID RV data also enable us to measure the spin-orbit misalignment, and we find that the exoplanet is on a retrograde orbit. The orbit of this new exoplanet is reminiscent of that of HD 80606 b, suggesting a shared dynamical origin for the two systems. We show that this is indeed likely to be the case, as the present extreme orbit of the planet is consistent with a history of Lidov-Kozai oscillations induced by the low-mass stellar binary companion. We also identify a statistically significant trend in the transiting warm Jupiter mass and eccentricity distributions, and we discuss implications for the processes responsible for sculpting the hot and warm Jupiter populations.

Theme(s): Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

31: The MASS-STRICT Project: Age Dating Clusters and Moving Groups using Binary Stars

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We present studies of eclipsing and interferometric binaries with precisely measurable masses in nearby clusters and groups, with the overarching goal of providing age calibration standards. The traditional age dating method of fitting theoretical isochrones to color-magnitude diagrams is almost always divorced from knowledge of stellar masses, and as a result there are very real possibilities of systematic errors in the models on top of the ones involved in the fitting process itself. We focus on binary systems containing rapidly-evolving stars to simultaneously examine the most age-sensitive stars while also testing the fidelity of the model physics. Our results cover clusters with ages from the 60 Myr \alpha Persei to the 100 Myr Pleiades to the 640 Myr Praesepe up to the 1.6 Gyr NGC 752. The results are particularly applicable to the calibration of gyrochronology. MASS-STRICT = Mass and Age Standard Stars - Studying Timing Reliability in Cluster Territory

Theme(s): New Insights into Star Formation and Evolution, Milky Way-scale Science and Big Data

32: The Companions to B and A Stars Snapshot (CBASS) Survey: 6 New Low-Mass Companions to B and A Stars

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Arizona State University; New Mexico State University; Northern Arizona University; Northwestern University; European Southern Observatory; University of California Santa Cruz; SETI Institute / University of California, Berkeley; University of Hawaii; University of Texas at Austin; University of Arizona; University of California, San Diego

We present results from the Companions to B and A Stars Snapshot (CBASS) Survey, an ongoing high-resolution demographics search for low-mass companions around nearby B and A stars using adaptive optics imaging with NIRC2 on the Keck II telescope. This survey allows for identification and characterization of brown dwarfs and M dwarfs in the intermediate stages of evolution. Companions detected through this study will provide a critical comparison to directly imaged star–planet systems and their atmospheres. The goal of the survey is to measure the demographics of brown dwarf companions to intermediate mass stars and expand the number of confirmed companion brown dwarfs. With a sample of wide-separation brown dwarf and low-mass stellar companions, we can quantify the location of the break between star and planet formation and determine the differences between star–star, star–brown dwarf, and star–planet

binaries. We completed a first-epoch companion search around over 200 young B and A stars within 200 pc, identifying over 170 candidate brown dwarf and low-mass M dwarf companions for follow up confirmation and characterization. We will discuss results from ongoing 2nd-epoch observations of our targets marked for follow up, including the discovery of at least six new M-dwarf companions. We are able to detect candidate companions that are ~15 magnitudes fainter than their host stars at distances beyond 1”, allowing us the sensitivity to detect wide-separation brown dwarfs.

Theme(s): Cool Stars as Stellar Systems, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

33: A Volume-Limited Radio Search for Magnetic Activity in 140 Exoplanets with the Very Large Array

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We present results from a search for radio emission in 77 stellar systems hosting 140 exoplanets, predominantly within 17.5 pc using the Very Large Array (VLA) at 4-8 GHz. We obtained new observations of 58 systems, and analyzed archival observations of an additional 19 systems. Our choice of frequency and volume limit are motivated by radio detections of ultracool dwarfs (UCDs), including T dwarfs with masses at the exoplanet threshold of ~13 M_J. Our targets span a mass range of ≈10^{-3}-10 M_J and semi-major axes of ≈10^{-2}-10 AU. We detect a single target - GJ 3323 (M4) hosting two planets with minimum masses of 2 and 2.3 $M_\oplus$ - with a circular polarization fraction of ≈ 40\%; the radio luminosity agrees with its known X-ray luminosity and the Güdel-Benz relation for stellar activity suggesting a likely stellar origin, but the high circular polarization fraction may also be indicative of star-planet interaction. For the remaining sources our 3\sigma upper limits are generally $L_\nu \leq 10^{12.5}$erg/s/Hz, comparable to the lowest radio luminosities in UCDs. Our sensitivity is comparable to predicted fluxes for some systems considered candidates for detectable star-planet interaction. Observations with future instruments such as the SKA and ngVLA will be necessary to further constrain emission mechanisms from exoplanet systems at GHz frequencies.

Theme(s): Cool Stars as Stellar Systems, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

34: Cross-matching X-ray and Gaia stars to constrain stellar rotational evolution

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We present preliminary results from our project that cross-matches Chandra X-ray sources with Gaia stars. We then compare the resulting X-ray properties with those expected, assuming different rotational evolution models. For the first part, we demonstrate that classical separation-based methods of cross-matching are inadequate, and develop a new Machine Learning based method to match and resolve ambiguous matches using associated properties like fluxes and colors. For the second part, we apply rotational braking models which exploit empirical rotation-dependent surface magnetic field complexity and physically realistic MHD wind models to define angular momentum evolution to Gaia-GUMS datasets, and compare the observed and predicted distribution of X-ray and optical properties.

Theme(s): New Insights into Star Formation and Evolution, The Sun and Cool Stars in the Time Domain

35: Insights from JWST spectra of two late L dwarfs

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We present our analysis of truly spectacular 1-22 µm JWST NIRSpec and MIRI spectra at R~2700 of two ~L7 brown dwarfs (program 2288, PI: Lothringer). 2148+4003 shows strong evidence of broad "silicate" absorption around 8-10 µm, while the feature is substantially weaker in 0624-4521. We compare the 1-22 µm observed spectra with several classic and new models, inferring physical properties and noting discrepancies. We analyze the composition of the broad silicate feature around 8-10 µm, constraining composition and particle sizes. We infer general cloud properties and assess whether JWST can spectroscopically distinguish patchy clouds from uniform clouds in a single observation. We analyze a few resolved ^{13}CO lines in a forest of more than 100 partially resolved ^{12}CO fundamental lines arising from the lowest three vibrational states. We set limits on temporal variability over the 3-4 hours of each observation. Finally, we speculate on why silicate absorption is so prominent in one object, but not the other.

Theme(s): Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

36: New X-Ray and Optical Observations of T-Tauri Star SU Auriga

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We present new XMM-Newton observations of classical T-Tauri star SU Auriga, a member of the 4 Myr old Upper Scorpius star forming region. SU Aur is a G2 spectral class star, hosting a highly inclined, dusty disk. Our data show an X-ray flare at the end of the observing period. We model the spectra using XSPEC models and measure the stellar abundances. Our results suggest a two-absorption component model provides the best fit to the data, indicating absorption by the circumstellar environment and additional absorption very close to the star, for example in the accretion column. We also obtained simultaneous and contemporaneous optical photometry and spectroscopy to understand the activity level. Unfortunately, though, the timing of the observations and the low amplitude of the X-ray flare prohibit the detailed flare studies we had hoped for in this observational program.

Theme(s): New Insights into Star Formation and Evolution, The Sun and Cool Stars in the Time Domain

37: The Gaia Ultra Cool Dwarf Sample: Database

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We present here the database for the Gaia Ultra Cool Dwarf Sample (GUCDS). The database is a store for thousands of spectra, photometry and astrometry. These are all able to be queried on, accessed and downloaded through a web interface or an API. This is a MySQL database with almost 9000 spectra and nearly 20000 sources. Each source has been cross-matched with data from Gaia, SIMBAD, 2MASS, AllWISE, PAN-STARRS, SDSS, Spitzer and the MKO filter system where appropriate.

Theme(s): Milky Way-scale Science and Big Data, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

38: A high-resolution H and K-band spectral atlas of the L7.5 and T0.5 components of Luhman 16

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We present an SNR~450 R=45,000 H and K-band spectroscopic atlas of the L7.5 and T0.5 components of the Luhman 16AB binary: the closest pair of brown dwarfs, and one of the best substellar benchmarks. The spectra were combined from a three-month spectroscopic monitoring campaign of the binary with IGRINS on Gemini South. We fit model spectra to the combined high-quality spectra to estimate atmospheric parameters. The model adds to the Sonora model atmosphere (Marley et al. 2021) the consideration of clouds and disequilibrium effects with the PICASO one-dimensional climate model (Mukherjee et al 2023). We discovered H_2 and H_2O absorption lines in both components of the binary, only the second near-infrared detections after Tannock et al. (2022) revealed them in the IGRINS spectra of a T6 dwarf. Methane and ammonia also show small contributions to our spectra even though their features are known to enhance at lower temperatures, and we find that the CH_4 lines are sensitive to the slight temperature difference across the L/T transition. We also investigate a variety of unidentified features, including absorption, emission, and P Cygni-like features that are ubiquitous around water-dominant regions. Although we searched for a planetary-mass companion by periodic analysis of the radial velocities over three months, we did not detect any significant signal.

Theme(s): Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

39: Multi-lines Stokes synthesis using ANN

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We present an Artificial Neuronal Networks (ANN) trained to reproduce the four Stokes parameters in a single line spectral lines or in multi-line profiles. We show that the ANN is able to recover very similar results as the ones using the codes that solves the polarized radiative transfer equation (pRTE): We show that the magnetic geometry of the stellar magnetic can be properly inferred using the ANN in the analysis of the data.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

40: X-ray superflares on three active RS CVn-type binaries

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We present an analysis of fourteen X-ray superflaring events observed on three RS CVn-type binaries: v711 Tau, UX Ari, and SZ Psc. The observations have been carried out with Swift, XMM-Newton, NICER, and MAXI observatories. Most of the flares are found to be in the category of long-duration X-ray flares with the flare-duration more than a day. From X-ray spectral analysis, the quiescent plasma of v711 Tau and SZ Psc are found to consist of three-temperature plasma, whereas for UX Ari the quiescent corona it is found to have a two-temperature plasma. The flare on SZ Psc and v711 Tau are identified to be simple flares whereas some of the flaring events detected on UX Ari using NICER observatories are identified to be complex flares. Using Hydrodynamic loop model we have estimated the length of the flaring loops, which are found to be of the order of 10^{11} cm. The high-level of magnetic activites on RS CVn type binaries are likely due to the extended convection zone of the subgiant component.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

41: 3D Simulation of Disk-Magnetosphere-Stellar Wind Interaction in Protoplanetary System

Ofer Cohen (1); Cecilia Garraffo (2); Jeremy Drake (3); Kristina Monsch (2); Igor Sokolov (4); Julian Alvarado-Gomez (5), Federico Fraschetti (2,6)
University of Massachusetts Lowell; Harvard-Smithsonian Center for Astrophysics; Lockheed Martin; Leibniz Institute for Astrophysics Potsdam; University of Michigan; University of Arizona

We present a three-dimensional, time-dependent MHD simulation of the short-term interaction between a protoplanetary disk and the stellar corona in a T Tauri system. The simulation includes the stellar magnetic field, self-consistent coronal heating and stellar wind acceleration, and a disk rotating at sub-Keplerian velocity to induce accretion. We find that, initially, as the system relaxes from the assumed initial conditions, the inner part of the disk winds around and moves inward and close to the star as expected. However, the self-consistent coronal heating and stellar wind acceleration build up the original state after some time, significantly pushing the disk out beyond 10R ⋆. After this initial relaxation period, we do not find clear evidence of a strong, steady accretion flow funneled along coronal field lines, but only weak, sporadic accretion. We produce synthetic coronal X-ray line emission light curves, which show flare-like increases that are not correlated with accretion events nor with heating events. These variations in the line emission flux are the result of compression and expansion due to disk-corona pressure variations. Vertical disk evaporation evolves above and below the disk. However, the disk-stellar wind boundary stays quite stable, and any disk material that reaches the stellar wind region is advected out by the stellar wind.

Theme(s): New Insights into Star Formation and Evolution

42: High Precision Astrometry: Not Just for Exoplanets!

Conaire Deagan

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Magnetic surface features of Sun-like stars are very difficult to detect to a sufficient precision to enable understanding of star-spot distributions, and thus inhibit knowledge about stellar dynamoes, differential rotation, and relative orientation to the exoplanet-analogue of the ecliptic plane. One upcoming mission - the TOLIMAN space telescope - is designed with innovative optics to achieve high-precision astrometry to detect the presence of an Earth-twin around either Alpha Cen A or B. This level of precision - better than 1 micro arcsecond - has opened new opportunities in stellar physics. These properties include relative inclination between the stars equator and the orbital plane of any planets, the magnitude and frequency of starspots, differential rotation curves, and potentially the presence (or absence) of a Sun-like dynamo. From simulations of the expected performance of TOLIMAN, if it hosts a Sun-like dynamo we expect to be likely able to measure the inclination of Alpha Cen A to better than 5 degrees. These insights will provide information regarding the stellar environment and habitability of any exoplanets present. Understanding the host star in detail is crucial, as things such as the stellar wind, the frequency and intensity of stellar flares, and the topology of the stellar magnetosphere directly impact the sustainability of biospheres in the surrounding environment.

Theme(s): New Insights into Star Formation and Evolution, Cool Stars as Stellar Systems

43: Understanding the Rotational Behavior of M dwarfs

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Pasadena City College; California Institute of Technology; Center for Astrophysics Harvard and Smithsonian

Low-mass stars, or M dwarfs, are the most common type of star in the Galaxy and the most likely host of Earth-like exoplanets. One of the main unresolved problems about M dwarf properties is that the rotational period evolution is not well understood. In this work, we studied the bimodal distribution of the rotational period of field low-mass stars. There are several explanations to this bimodality such as magnetic dynamo, initial conditions, magnetic field topology or binarity. In this study, we tested the binarity explanation. We used low-mass stars from Newton et al. (2017) and cross-matched them with Gaia DR3. For binary classification, we used three different binary indicators from Gaia: RUWE (Renormalised Unit Weight Error), rv_amplitude_robust (variability in radial velocity), and ipd_frac_multi_peak (an indicator for unresolved companions). We analyzed the remaining single stars and found that there is still a significant number of fast rotating single stars. Our analysis also shows that the bi-modal distribution of rotation periods of single stars is more distinct for fully convective stars than partially convective stars, and that it is also present for binary stars.

Theme(s): New Insights into Star Formation and Evolution, The Sun and Cool Stars in the Time Domain

44: Evidence for Rapid Rotational Evolution of M Dwarf Stars Near the Fully Convective Boundary

Lydia Miller; Gregory Feiden
University of North Georgia

Low-mass stars spin-down with time due to angular momentum loss from magnetized stellar winds. Spin-down was thought to be a continuous process, but recent observations suggest that spin-down stalls for up to 2.0 Gyr among stars with a radiative core. The stalling duration increases as stellar mass decreases down to the fully convective boundary, below which stars do not appear to stall their spin-down. Near the fully convective boundary ($M_{G} \approx 10$), stars are expected to oscillate between partially and fully convective states, and it is not clear how these oscillations affect a star's rotational evolution. Using over 400,000 measured rotation periods from the Zwicky Transient Facility (ZTF), we find these stars behave similar to more massive, partially convective stars. However, there is a group of stars with $10.3 \lesssim M_G \lesssim 10.7$ that have rotation periods up to 50 days slower than expected and show no evidence of rotational stalling. We find these stars are kinematically younger by /approx 1.5 Gyr despite the expectation that they should be ≈ 1.0 Gyr older based on a Skumanich spin-down law. This suggests a rotational evolution that is 1.8 and 1.2 times faster than for partially and fully convective stars, respectively. Finally, we plausibly connect this rapid rotational spin-down with the stars' unique interior structure evolution.

Theme(s): New Insights into Star Formation and Evolution, The Sun and Cool Stars in the Time Domain

45: Convective Deepening as the Driver of Rotational Spin-down Stalling

Gregory A. Feiden; Lydia Miller
University of North Georgia

Low-mass stars slow their rotation over time. Their outer convective envelopes lose angular momentum to magnetized stellar winds while latent angular momentum stored in a more rapidly rotating radiative interior leaks outward. As a result, surface rotation periods are observed to increase proportionally with age, $P \propto \tau^\beta$ where $\beta \sim 0.5$. More recent evidence suggests that rotational spin-down is severely weakened for a length of time that depends on stellar mass. Using a simplified model of stellar angular momentum evolution, we demonstrate that the epoch of stalling coincides with a stage in the lives of low-mass stars where their outer convective envelopes deepen and grow in mass. We artificially evolve slow-rotating stars from Praesepe assuming a spin-down law with $\beta = 0.6$. However, during times where stellar evolution models suggest stars are undergoing a convective deepening, we test scenarios where $\beta = 0.0, 0.2, 0.4, 0.6$. We find that $\beta = 0.2$ during convective deepening reproduces observed rotational sequences for cluster stars with ages between 0.7 and 4.0 Gyr. Disagreements are still observed among the evolution of early-M dwarf stars. Our results suggest that rotational stalling is a consequence of convective deepening. We discuss possibilities that stalling is due to enhanced transport of angular momentum from the stellar core, or a reduction in wind-breaking efficiency.

Theme(s): New Insights into Star Formation and Evolution, The Sun and Cool Stars in the Time Domain

46: Towards a unified framework of spin, mass-loss, magnetic field and XUV evolution of low-mass stars

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Low-mass stars exhibit intriguing trends in the evolution of their spins, magnetic fields, winds, and stellar activity. These are interlinked and most likely driven by a fundamental mechanism. Here we highlight our efforts to model this fundamental mechanism by constructing a simple model for the evolution of the internal and surface spins of fully convective M dwarfs (FCMDs) and partly convective dwarfs (PCDs). In our model, the spin of the radiative core (if any) is governed by shear at the core-envelope boundary while the spin of the convective envelope (star) is governed by magnetic braking (MB) and shear. Our MB mechanism is an \alpha-\Omega dynamo, which leads to stellar winds that carry away angular momentum. We find that our model results of the evolution of the stellar spin, wind mass loss, and surface magnetic field are in general agreement with observations, and that in PCDs, the core-envelope convergence time not only depends on the stellar mass but also the spin. We use these ingredients to probe the evolution of stellar activity (XUV). We find that XUV evolution not only depends on stellar mass and age but also on the spin of the star. This spin-dependence of XUV evolution introduces an additional complexity that is seldom captured by simple empirical models. We show that the results from this study can be extended to undertake robust studies of stellar activity-driven atmospheric loss of exoplanets.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

47: The EaRTH Disk Model: Understanding Protoplanetary Disk Mineralogy and Structure

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Our understanding of how exoplanets form and evolve relies on analyses of both the mineralogy of protoplanetary disks and their detailed structures; however, these key complementary aspects of disks are usually studied separately. We present initial results from a hybrid model that combines the empirical characterization of the mineralogy of a disk, as determined from its mid-infrared spectral features, with the MCFOST radiative transfer disk model, a combination we call the Empirical and Radiative Transfer Hybrid (EaRTH) Disk Model. With the results of the mineralogy detection serving as input to the radiative transfer model, we generate mid-infrared spectral energy distributions (SEDs) that reflect both the mineralogical and structural parameters of the corresponding disk. Initial fits of the SED output by the resulting integrated model to {\it Spitzer Space Telescope} mid-infrared (IRS) spectra of the protoplanetary disks orbiting nearby T Tauri stars demonstrate the potential advantages of this approach by revealing, for example, the dominance of pyroxene, olivine and forsterite in the dusty disk orbiting the nearby, young solar analog MP Mus. The simultaneous insight into disk composition and structure provided by the EaRTH Disk methodology should be directly applicable to the interpretation of mid-infrared spectra of protoplanetary disks that will be produced by the James Webb Space Telescope.

Theme(s): New Insights into Star Formation and Evolution, Cool Stars as Stellar Systems

48: TESS Stellar Variability Catalog (TESS-SVC)

Tara Fetherolf (1,2); Joshua Pepper (3); Emilie Simpson (4); Stephen R. Kane (2); Teo Mocnik (5); John Edward English (6); Victoria Antoci (7); Daniel Huber (8); Jon M. Jenkins (9); Keivan Stassun (10); Joseph D. Twicken (4); Roland Vanderspek (11); Joshua N. Winn (12)

CSU San Marcos; UC Riverside; Lehigh University; SETI Institute; Gemini Observatory; UC Irvine; Technical University of Denmark; University of Hawai'i; NASA Ames; Vanderbilt University; MIT; Princeton University

The TESS spacecraft obtained high-precision space-based time-series photometry of nearly the entire sky during its Prime Mission, allowing for a large-scale study of stellar variability that is not sensitive to the diurnal limitation of ground-based surveys. We present the TESS Stellar Variability Catalog (TESS-SVC), which includes ~84,000 stars that exhibit significant photometric variability on timescales of 0.01-13 days. The TESS-SVC includes a broad range of

periodic variable stars (rotation, pulsation, eclipsing binaries, etc.) that were selected based on a photometric periodogram analysis of their 2-min cadence light curves. The TESS-SVC is now available as a HLSP on MAST that includes tabulated information about the periodic variability measured and a summary figure for each star that shows the resultant periodogram and best-fit curve to the stellar variability. The catalog will continue to be updated as new TESS data becomes available, and it will later include stars that exhibit photometric variability on timescales longer than 13 days. I will discuss the characteristics of the stars in the TESS-SVC, which will serve as a valuable resource to the stellar astrophysics and exoplanet communities. The variability catalog will aid in 1) studying the characteristics of periodic variable stars; 2) understanding interactions between host star variability and planetary atmospheres; and 3) identifying exoplanets that are actually false positives caused by stellar variability.

Theme(s): Milky Way-scale Science and Big Data, The Sun and Cool Stars in the Time Domain

49: Precise Masses for HD 16160 AB from a Joint RV+Astrometry Analysis

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The precision of stellar models is higher than the precision at which we are able to measure the masses of most stars, with the notable exception of binaries where we can determine dynamical masses of the component stars. Currently, there are only a small handful of stars for which we have precise ($\lesssim 3 \%$), model-independent mass measurements that widely-enough separated to not be impacted in their structure/evolution by their companion and for which we can obtain clean spectra. Here, we introduce HD 16160 A and HD 16160 B as members of that list. We present an updated orbital analysis for the long-period K3+M7 binary HD 16160 AB. We jointly analyze radial velocity and relative astrometry data, including new RVs from the Miniature Exoplanet Radial Velocity Array (MINERVA) that capture the full periastron passage and the RV minimum of the 77.1 ± 1.4 year orbit for the first time. Additionally, we derive precise dynamical masses of $M_1 = 0.79 \pm 0.02 M_\odot$ and $M_2 = 0.096 \pm 0.002 M_\odot$.

Theme(s): New Insights into Star Formation and Evolution, Cool Stars as Stellar Systems

50: Numerical quantification of the environment of F, G, K and M main sequence stars

Judy J. Chebly, Julián D. Alvarado-Gómez, Katja Poppenh\"{a}ger, Cecilia Garraffo
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Direct observation of stellar winds is difficult, which is why astronomers resort to indirect methods such as the astrospheric technique. However, this approach has several limitations and is only applicable to a few stars. This motivates the use of computer simulations and models to predict the various properties of stellar winds. In our work, we used a state-of-the-art 3D MHD model driven by the large-scale magnetic field distribution of 21 well-observed stars. We provide the first systematic study of the stellar wind properties expected for F to M stars. In this talk, I will present results that challenge previous assumptions about wind speed and the associated mass loss. Our analysis showed a wide range of wind speeds across the spectral types and within the same spectral type. These results emphasize the importance of using the appropriate wind speed when estimating mass loss from astrospheric technique. I will also present a predictive model that can be used to determine the size of the Alfv\'en surface, which is crucial for understanding star-planet magnetic interactions. In addition, I will provide insights into the wind conditions at the habitable zones of each star in our sample. Our study has shown that wind conditions around F and G-type stars are milder, similar to what the Earth experiences around the Sun, while K and M-type stars provide harsher wind conditions. These results of this study are general enough to be applied to other cool main sequence stars.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

51: The Roman Road to Stellar Rotation: Rotation and Spots with Roman's Time Domain Surveys

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We have used machine learning to study stellar rotation in TESS despite the mission's complicated systematics. The upcoming Nancy Grace Roman Space Telescope will perform time domain surveys at multiple wavelengths that stand to increase the number of period measurements and offer temperature resolution for star spot properties, shedding light on the connections between rotation and magnetism. However, the survey design is not yet decided, and certain choices may be critical to ensure sufficient cadence, baseline, and wavelength coverage for stellar rotation science. We are using the simulation and machine learning framework developed for TESS to predict the optimal Roman survey design for stellar rotation. I will discuss our framework and illustrate how existing machine learning tools can inform decisions for survey design. I will consider the stellar populations and periods Roman will be sensitive to and preview the transformational science Roman will enable.

Theme(s): The Sun and Cool Stars in the Time Domain

52: Overfitting, Unresolved Stellar Activity, and the 20 Myr V1298 Tau Planetary System

Sarah Blunt
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Suárez-Mascareño et al 2021 (SM21) measured the masses of two transiting giant planets around the 20-Myr pre-main sequence star V1298 Tau using radial velocities (RVs) from multiple independent spectrographs. They found surprisingly high masses for both planets, implying densities comparable to those of the most dense mature giant planets. This result was in tension with the theory of formation via core accretion, which predicts that giant planets have low densities upon formation, and contract as they age and cool. In this presentation, I will show evidence that the preferred model of SM21 suffers from overfitting, affecting the reliability of the mass measurements (Blunt et al 2023a). I'll discuss why the overfitting occurs, and in particular explain how stellar activity processes that are unresolved in the time domain, particularly differential rotation, can masquerade as overdense planets when RV data are poorly sampled. I will conclude by foreshadowing the Time-resolved Activity Processes of Young Stars (TRAPYZ) RV survey, a very high-cadence survey of nearby young stars intended to fully resolve stellar activity processes in the time domain to enable accurate joint modeling of stellar and planetary signals.

Theme(s): The Sun and Cool Stars in the Time Domain

53: Like Star like Planet: How Do Planet Properties Affect the Chemistry of Planet-Hosting Stars?

Francisco Mendez; Rana Ezzeddine
University of Florida

With thousands of exoplanet discoveries, the factors driving planetary system diversity remain elusive. Since stars and their planets form from the same material, comparing their chemical compositions can shed light on the environments where exoplanets form. We developed a spectral synthesis pipeline to derive stellar parameters and refractory element abundances, which was validated using Gaia-ESO benchmark stars, yielding results consistent with literature values. We then applied a doppelganger analysis to over 100 HARPS stars to assess intrinsic chemical differences between planet-hosts and non-hosts. We find that low [Fe/H] planet-hosts are enriched in refractory elements as compared to non-hosts. In particular, small planet hosts show enhancement up to ~0.3 dex for Mg, and ~0.15 dex for Ca and Ti, while giant planet hosts show enhancement up to ~0.3 dex for Mg and Ti, and ~0.15 dex for Ca and Sc. This enhancement decreases to 0 as [Fe/H] increases. We further investigated the influence of exoplanet properties (mass and orbital period) as a function of abundance difference and found no statistically significant trends. Interestingly, stars hosting a larger number of small rocky planets show a larger depletion of refractory material compared to non-hosts. Our findings reveal diverse relations between [Fe/H], exoplanet properties, and the abundance of refractory elements in host-stars, providing valuable insights into the diverse environments where exoplanets form.

Theme(s): Cool Stars as Stellar Systems, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

54: Accretion Properties of a Young Brown Dwarf

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Rice University; Cornell University

Young stars which have just emerged from their natal nebulae go through a very active T Tauri phase, where accretion of material from the circumstellar disc onto the star plays an important role in both the star's evolution and its ability to host planets. The accretion properties of low-mass stars have been relatively well-studied, and recently accretion onto planetary mass objects has been proposed. Brown dwarfs are the link between low-mass stars and giant planets. Here I present HST observations of a young 52M_{\mathrm{jup}} brown dwarf, J0844, that exhibits signs of accretion. I analyse the C IV doublet in terms of an accretion and/or magnetic activity origin, and find that J0844 shows a much lower level of C IV emission compared to the magnetic activity level of T Tauri stars, as well as much narrower line profiles akin to those of weak T Tauri stars. In order to estimate the level of emission from magnetic activity, I compare the C IV emission to other non-accreting magnetically-active late M-type stars VB 8, VB 10 and LHS 2065. In comparison to these, J0844 shows a larger amount of C IV flux indicative of accretion processes in addition to its transition region activity. Studying objects such as J0844 will help extend our current knowledge of stellar accretion down to the lowest masses, and into the planetary regime.

Theme(s): New Insights into Star Formation and Evolution, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

55: Aurorae, Clouds or Magnetic Spots? Disentangling drivers of variability in three early L-Dwarfs

Cian O'Toole (1); Johanna Vos (1); Melodie Kao (2); Sebastian Pineda (3); Merle Schrader (1); Yifan Zhou (4)
Trinity College Dublin; UC Santa Cruz; University of Colorado Boulder; University of Virginia

Brown dwarfs provide unique insights into exometeorology - weather on extrasolar objects. They act as powerful analogs to directly imaged exoplanets, due to their similar position on colour-magnitude diagrams. They provide a wealth of information as to how both of these substellar populations form and evolve as they can be observed far easier than directly imaged exoplanets. This study investigates the spectroscopic variability of three early L-type brown dwarfs, 2M0036+18, 2M1721+33 and 2M1906+40, using a novel approach of simultaneous observations from HST/WFC3 at near-IR wavelengths and the VLA in the radio (4-12 GHz). Early L-Dwarfs are especially interesting as they are at the right temperature to allow a number of processes to occur that are not possible at other spectral types including any one of, or a combination of, aurorae, clouds and magnetic spots. This allows different insights into the atmospheric processes in giant extrasolar worlds. We use the HST data to distinguish between the various drivers of variability and potentially detect auroral activity in the near-IR for the first time. 2M0036+18 is a known auroral emitter in the radio, while 2M1721+33's variability is

primarily due to condensate clouds. The final case however, 2M1906+40, has ambiguous behaviour. All three objects show significant variability in the HST observations and we aim to disentangle the drivers of variability in each object by analysing their unique signatures of variability.

Theme(s): Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

56: We Didn’t Start the FIRE: T dwarf Kinematics Project

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Brown dwarfs are substellar objects without the capacity to fuse hydrogen. They thus have no stellar lifetime and can be excellent age tracers for the populations in which they reside. Determining the age of a brown dwarf is difficult, however, due to the degeneracy between age, temperature, and mass; we need an independent measure of age. It is known that the velocity dispersion of a population increases with age; by examining the velocity dispersion of brown dwarfs, we can infer their collective age. Velocity dispersion ages are well studied among the late-M and L dwarf spectral types, but there are few T dwarfs with the 3D velocities needed to realistically use this statistic. In this paper, I present mid-resolution infrared spectra of 55 T dwarfs observed with the Magellan Folded-port InfraRed Echellette (FIRE) Spectrograph. I reduced and extracted the spectra, and used SMART, a Markov Chain Monte Carlo (MCMC) forward-modeling code, to determine atmospheric parameters and RV for J0817-6155, the brightest source in the sample. I measure an RV to be 2 \pm 7 km/s, logg = 5.39 \pm 0.18dex and Teff = 1205 \pm 11.8K. My RV value does not significantly differ from a previously reported velocity of this source. I discuss the steps I intend to improve within my fitting procedure, including the implementation of vsini in the model fits and the inclusion of newer models, and anticipated science for analysis of the full sample.

Theme(s): The Sun and Cool Stars in the Time Domain, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

57: Towards the measurement of small-scale magnetic fields of slow rotators.

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Center for Astrophysics | Harvard and Smithsonian

M dwarfs represent more than 70% of the stars in the solar vicinity and yet, constraining their property remains a technical challenge because of their complex atmospheres. Those stars are also magnetic, and constraining their magnetic properties is crucial to understand the processes at the origin of magnetic field generation, stellar formation and evolution. In this poster, we present the results of efforts aimed at estimating the magnetic fields of dozens of slow rotating M dwarfs from high-resolution spectra recorded with SPIRou, relying on synthetic spectra modeled with ZeeTurbo. Our results show a spread in the average magnetic field strength for

targets found in the unsaturated dynamo regime: the spectra of several star being well reproduced by non-magnetic models, while other stars with similar Rossby number are better modeled with magnetic synthetic spectra. Our results represent a step further towards the broader objective of developing tools for accurately characterizing magnetic M dwarfs from high resolution spectra recorded with various instruments. Those results and tools aim at providing the essential data needed to address questions related to the generation of magnetic field in low-mass stars.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

58: Localizing Stellar Activity on Low-Mass Stars with the Transiting Exoplanet Survey Satellite

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Magnetic reconnection is the underlying cause of stellar flares, which are more likely to occur in regions of high magnetic activity, such as star spots. The rapid rotation and deep convection of young low-mass stars leads to heightened magnetic activity and a substantial increase in the rate of flares. By further understanding stellar activity, we are able to constrain how they affect observations such as radial velocity measurements and transmission spectroscopy. We analyze 120-second cadence light curves of young low-mass stars observed by the Transiting Exoplanet Survey Satellite (TESS) to investigate trends in flare times and frequency in relation to star spot modulation signals. TESS constantly monitors nearby stars, enabling the study of this flare-spot connection for a variety of star parameters such as age, temperature, and rotation rate. Trends in flare properties and spot modulation can provide a means to "localize" on which face of a star flares occur more frequently and better understand their association with active regions. We present a preliminary analysis of light curves from M and K dwarfs with no companions from five nearby and young moving groups: \beta Pictoris, AB Doradus, Tucana-Horologium, Columba, and Carina, spanning ages \sim 20 to 150 Myr. We discuss our techniques to analyze the distribution of flares across the rotation phase for stars in this sample and describe future improvements.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

59: TOI-700 d: Assessing Habitability Under UV Radiation and Atmospheric Haze Conditions

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Planets orbiting within the habitable zone (HZ) of M stars face the risk of high-energy radiation, which can erode their atmospheres over time. Among these stars, TOI-700 is an intriguing target. This quiet star hosts four planets, including TOI-700\,d, a rocky planet situated within the HZ. This study focuses on TOI-700\,d, evaluating its potential atmosphere and habitability, with a particular emphasis on the role of hazes in the modeled atmospheres, which offers a novel insight into this Earth-like exoplanet. To achieve this, we employed a 1D photochemistry code coupled with the climate ATMOS model, simulating both modern Earth-like and Archean atmospheres to elucidate the atmospheric composition. Although TOI-700 is often quiescent, we simulated a scenario with enhanced flare sufficient to match the relative NUV irradiance levels at the top of the atmosphere to those of the young Sun and Earth, based on stars of the same spectral type. We also conducted simulations without UV amplification for comparison. The impact on habitability is not considered critical. Both common and extremophile bacteria could potentially survive on the planet under various atmospheric conditions in most scenarios. Interestingly, haze presence could significantly influence habitability, possibly having a greater impact than ozone under certain conditions. However, these UV radiation absorbers might also hinder the formation of RNA precursors.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

60: VLASS Sources Associated With Super-flaring Solar-Type Stars from The First Year of TESS Data

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A blind transient search in the Very Large Array (VLA) Sky Survey (VLASS) by Dong et al (in prep) reveals an impressive collection of stellar radio transients at GHz frequencies (Ayala et al (in prep)). Two of the stars identified are young, solar-type stars that exhibit flares in the Transiting Exoplanet Survey Satellite (TESS) data. Prompted by this coincidence, we use the stars in TESS flare catalogs for solar-type stars produced by Tu et al. (2020) and Doyle et al. (2020) to inform our search for radio emission within the VLASS epochs 1 and 2. This led to us finding four additional single, active, solar-type stars with associated VLASS sources. Here we present the properties of these six stars as they compare to the larger TESS superflaring sample to explore the possible relation between the optical component and the nonthermal radio emission despite the non-simultaneity of the catalogs. Two of these stars have radio emission in both epochs, and two have high circular polarization fractions. Given the flare rates, flare energies, polarization fractions, and the six stars' adherence to the G\"udel-Benz relation, we conclude much of the radio emission is likely associated with superflares and that most of the TESS superflare sample should produce detectable radio bursts. This emphasizes the importance of GHz radio surveys for identifying active stars and understanding the particle acceleration processes– and particle environments– of young, solar analogs.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

61: The Young Star Radius-Rotation Period Parameter Space

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Young star radii and surface gravities provide a physical measure of contraction and age, a notoriously challenging parameter to estimate but key to understanding the evolution of young systems in the planet-forming and circumstellar disk-dispersing epoch. By measuring projected rotational velocities from high-resolution spectra and stellar rotation periods from K2, TESS, and ground-based light curve periodograms, it is possible to determine lower limits for young star radii. We compare these results to radii predicted from models for a sample of single and binary stars in the Taurus star forming region.

Theme(s): New Insights into Star Formation and Evolution, The Sun and Cool Stars in the Time Domain

62: Resolving Accretion onto the Giant Exoplanet DH Tau b

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Rice University; Cornell University; Boston University

As giant planets form, it is expected they become surrounded by circumplanetary disks embedded within a circumstellar disk. Forming planets are expected to gain additional mass and angular momentum by accreting material from these circumplanetary disks. However, key questions remain such as: What is the geometry of the accretion flows onto forming giant planets? and, How rapidly do they accrete material from their disks? For example, accretion could occur through an equatorial boundary layer or through a magnetically controlled funnel flow similar to how young stars accrete material from their circumstellar disks. High resolution spectrosccopy of emission line profiles can constrain the geometry of the accretion flow, and the line flux can be used to estimate the accretion rate. Here, we use the HIRES on Keck I to, for the first time, both spatially and spectrally resolve the H\alpha line profile from DH Tau b, an 11 M_{Jup} giant planet accreting material within the disk of DH Tau. Preliminary results show the measured line profile is single peaked with a FWHM of ~50 km/s, and its shape is generally consistent with expectations from magnetically controlled accretion models. The measured line luminosity gives a preliminary accretion rate of about 10^{-7} to 10^{-6} M_{Jup} yr^{-1}, depending on whether stellar or planetary mass accretion rate calibrations are used. We present these results and discuss their implications.

Theme(s): New Insights into Star Formation and Evolution, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

63: Conjectures on Photosynthesis and Evolution in the TRAPPIST-1 System

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San Diego State University

Oxygenic photosynthesis arose about ~3 Gyrs ago, yet 700 million more years would pass before oxygen levels rose to an appreciable amount – the "Great Oxidation Event" (GOE). Assuming this time lag is proportional to the rate of oxygen production, we can estimate how long it would take for a GOE-like event to occur on a hypothetical Earth orbiting TRAPPIST-1. Oxygenic photosynthesis uses light in the PAR (Photosynthetically Active Radiation) range: 400-700 nm. TRAPPIST-1 is an ultracool M dwarf, and if Earth were in TRAPPIST-1e's orbit, it would be in the habitable zone but receive only 0.9% of the PAR photons it gets from the Sun. If oxygen production is linearly proportional to the number of PAR photons, it would take a staggering ~77 Gyrs to reach a GOE. But the linear assumption is poor: as light levels increase, photosynthesis saturates then declines. Accounting for such "photoinhibition", as well as tidal locking, stellar evolution, and extending the PAR 50 nm to the red yields a ~4 Gyr time lag between the origin of oxygenic photosynthesis and a GOE. A Cambrian explosion would take ~15 Gyrs. By contrast, non-oxygenic photosynthetic bacteria can use light out to 1100 nm, and for TRAPPIST-1 this gives 55x more photons! Such bacteria would dominate over oxygen-producing cyanobacteria. On such a hypothetical planet a GOE would not occur, let alone a Cambrian explosion, and thus complex animal life should not exist. Real TRAPPIST-1 planets may share this same fate.

Theme(s): Cool Stars as Stellar Systems, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

64: Simulations of Electron Beam Interactions with Substellar Atmospheres

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The atmospheric evolution of substellar objects is governed by thermospheric and exospheric conditions, which modulate atmospheric mass-loss processes. Electrons (produced via magnetospheric dynamics or host-satellite interactions) incident on predominantly H_2 atmospheres can ionize H_2, driving the formation of H_3^+. For gas giant planets in the Solar System, H_3^+ cools the upper atmosphere through infrared emission. Future observations of H_3^+ in extrasolar substellar atmospheres could serve as a powerful diagnostic of atmospheric structure and temperature. Furthermore, electron impact excitation of H_2 can produce UV aurorae, and the observation of such aurorae would provide evidence of electron precipitation. The discovery of radio aurorae in brown dwarf atmospheres demonstrates the presence of auroral processes beyond the Solar System, with UV, optical, and IR aurorae also theoretically predicted. Simulations of high energy electron interactions with substellar hydrogen dominated atmospheres will guide observational searches for multi-wavelength auroral features in exoplanetary atmospheres. We present initial results of a simulated electron beam interaction with various H_2 atmospheres. As a first step, we focus on the ionization profile, which is needed to understand the atmospheric chemistry effects of the electron beam, including the formation of H_3^+. We consider electron beam interactions with atmospheres of both gas giants and brown dwarfs.

Theme(s): New Insights into Star Formation and Evolution, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

65: Using low resolution optical spectra to identify young stars and their properties

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Stellar spectra are a valuable tool for understanding young pre-main sequence stars. Some spectral lines, such as Li I, can be a direct indicator of stellar youth while other lines, e.g., H alpha or Ca II, can be used as a tracer of either disk accretion or magnetic activity that is also heightened in young stars. In our research, we used low resolution optical spectra collected from the fifth iteration of Sloan Digital Sky Survey (SDSS-V) to develop different techniques to perform a spectroscopic identification of YSOs and to analyze their properties. We present a data-driven pipeline, LineForest, that autonomously measures the equivalent width of 52 different lines in the optical spectra, including Li I, Balmer series, Paschen series, and a number of lines that can be seen in emission due to accretion. Using these lines, we construct a classifier that, to date, has confirmed the youth of >18,000 stars, including >5500 classical T Tauri stars (CTTSs). Through modeling the decrement of the lines in the Balmer series, we estimate the properties of the accretion stream of these CTTSs, such as the temperature of the accretion flow and its surface density. We examined the evolution of Li I depletion as a function of age, developing an empirical model of Li I absorption for stars with 3200 Theme(s): New Insights into Star Formation and Evolution

66: The magnetic and spin-down properties of slowly rotating M dwarfs

Victor See (1); Louis Amard (2); Stefano Bellotti (3,4); Sudeshna Boro Saikia (5); Emma Brown (6); Jean-Francois Donati (4); Rim Fares (7); Adam Finley (2); Colin Folsom (8); Élodie Hébrard; Moira Jardine (9); Sandra Jeffers (10); Baptiste Klein (11); Lisa Lehmann ; Stephen Marsden (6); Sean Matt (12); Matthew Mengel (6); Julien Morin (13); Pascal Petit (4); Aline Vidotto (3); Ian Waite (6)
ESA/ESTEC, The Netherlands; CEA Saclay, France; Leiden University, The Netherlands; IRAP, University of Toulouse, France; University of Vienna, Austria; University of Southern Queensland, Australia; United Arab Emirates University, United Arab Emirates; University of Tartu, Estonia; University of St Andrews, UK; Max Plank Institute for Solar

System Research, Germany; University of Oxford, UK; University of Oklahoma, USA; University of Montpellier, France

Over the past two decades, Zeeman-Doppler imaging (ZDI) has been used to study the magnetic field strengths and topologies of low-mass stars over a wide range of spectral types and rotation rates. A notable absence from these works was slowly rotating mid/late M dwarfs. However, this has been rectified by recent ZDI studies. These studies showed that slowly rotating late M dwarfs appear to have stronger magnetic fields than one might expect based on their position in the activity-rotation relation. In this poster, I will look at the magnetic properties of these new stars in more detail and compare them to the magnetic properties of other stars across the HR diagram that have been mapped with ZDI. I will also use the ZDI maps of these slowly rotating M dwarfs, in conjunction with braking laws, to estimate their angular momentum loss rate and to shed light on the puzzling rotation evolution of M dwarfs.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

67: Red Supergiants in the Local Group: Closing the Loop on Massive Star Evolution

Philip Massey
Lowell Observatory

Over the past few years complete populations of red supergiants (RSGs) have been identified in most of the star-forming galaxies of the Local Group. I will briefly discuss how well the relative number of RSGs and Wolf-Rayet stars scale with metallicity in comparison with BPASS binary population models, and also what the RSG luminosity functions have taught us about the time-averaged mass-loss rates of these stars.

Theme(s): New Insights into Star Formation and Evolution, Cool Stars as Stellar Systems

68: Long-Baseline Optical Interferometric Images of Sun-like Stars Helping RV Companion Searches

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University of Michigan, Ann Arbor, USA; Yale University, New Haven, USA

Nearby, low-mass, main-sequence stars are routinely being monitored with extreme precision radial velocity observations in search of new exoplanets. However, the detection of Earth-like exoplanets in Earth-like orbits around cool, Sun-like stars is inhibited by the radial velocity signatures of the stars themselves, which are intertwined with those of planets. To account for the impact of the stellar surfaces on radial velocities, we resolve nearby, Sun-like stars with long-baseline optical interferometry. Together, the H-band MIRC-X and K-band MYSTIC beam combiners and all six telescopes at the 330-m CHARA Array at Mount Wilson Observatory are capable of resolving our target stars. Not only are the stars resolved, but this interferometric

array uniquely has the necessary resolution to allow for the study of features on the stellar surfaces, including dark starspots caused by strong magnetic fields stifling convection. After interferometrically imaging a star, we then model the surface's radial velocity signature and compare to contemporaneous observations from extreme precision radial velocity spectrographs, including EXPRES. This comparison then allows for the investigation of potential planetary signatures otherwise hidden by the star's own radial velocities. Here, we present the results from our study of four nearby, Sun-like stars and our plans for further applications of the technique.

Theme(s): Cool Stars as Stellar Systems

69: Explaining the Diversity of Cold Worlds: a Forward Model Analysis of Y Dwarf JWST Observations

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In this poster, I present results from a forward model analysis of a sample of 12 late T and Y dwarfs observed in JWST GO program 2124. At effective temperatures of 250 - 800 K, these objects provide a bridge between the atmospheric regimes of brown dwarfs and Solar System gas giants, and they anchor the low mass end of the IMF. Explaining their characteristics thus has implications for understanding both star formation and the processes that shape giant planet atmospheres. GO 2124 collected NIRCam G395H spectra (R~2700 spanning 2.75-5.15 microns), targeting a wavelength region strongly influenced by disequilibrium chemistry. I use two model grids, Sonora-Elfowl and Lacy & Burrows 2023, to infer temperatures, surface gravities, chemical compositions, and mixing strengths across the sample. I then summarize implications for the causes behind the structure of the cold brown dwarf CMD, and the implications for improving upon existing 1D RCE model grids.

Theme(s): Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

70: Characterizing Young Stellar Properties and protoplanetary disks in the Orion OB1 Association.

C.E. Zepeda (1); C.G. Román-Zúñiga (1); J. Hernández (1); L. Adame (1); R. López-Valdivia (1); A. Bayo (2).

Instituto de Astronomía - Universidad Nacional Autónoma de México, Ensenada, México; European Southern Observatory.

In this work, our goal is to study how the presence of a circumstellar disk and the local extinction affect the determination of stellar parameters in a sample of near-infrared stellar spectra of stars in the Orion OB1 region, obtained a part of the SDSS APOGEE-2 and Milky Way Mapper programs. We use the TONALLI code (L. Adame, 2024), designed to obtain stellar properties through a heuristic, unsupervised process that compares observed and synthetic spectra across a model grid. We found that some stellar properties (Teff, logg) in YSOs depend strongly on dust extinction level (Av) and protoplanetary disk properties. We estimate and remove extinction through photometry, showing how we significantly improve the parameter estimation with TONALLI. Also, we use VOSA (Bayo, 2008) and SEDfitter (Robitaille, 2007) tools to obtain stellar properties and disk parameters independently, searching for systematic effects in the stellar parameter determination. We aim improve parameter ranges a priori, and to explain the influence of certain circumstellar disk features on stellar characterization. Our recent findings underscore the significant role of interstellar extinction in spectral-type characterizations, particularly in the estimation of surface gravities.

Theme(s): New Insights into Star Formation and Evolution

71: The Soft Emancipation of Young Stars from their Parental Clouds

Carlos Román-Zúñiga (1); Sergio González (1); Itzarel Hernández (1); Martha Hernández (1); Lucia Adame (1); Ricardo López-Valdivia (1); Jesús Hernández (1); Nadia Murillo (1); Mónica Villa (2); Jorge Barrera-Ballesteros (2), Marina Kounkel
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Spectroscopic surveys currently engage the detailed study of the early evolution of stellar clusters by allowing to estimate physical and kinematic properties of young stars. Moreover, we are now in position to compare the kinematics of stars and their parental gas, using distinct tracers for the interstellar medium, from ionized gas in through IFU mapping (e.g. SDSS LVM) to molecular gas in CO map surveys (e.g. MWISP). We present results of our study of stellar groups and their parental medium in the Rosette, Cygnus-X and Vela Ridge complexes. We can confirm that in the presence of massive stars, the parental gas is removed in a timescale comparable to that of circumstellar material, with stellar clusters clearly expading as they emerge from their cloud. Moreover, the motion of stars, while disengaging from that of molecular and ionized gas, is intimately linked to them for the first few million years after star formation. We also work on the tracing of young star moving groups through stellar youth tracers, aiming to understand the incorporation of young clusters to the Galactic thin disk population.

Theme(s): New Insights into Star Formation and Evolution, Milky Way-scale Science and Big Data

72: An Ultrashort-Period, Ultracool Dwarf Transiting an M dwarf

Akihiko Fukui (1,2); Takato Tokuno (1); Takeru K. Suzuki (1); Norio Narita (1,3,2); the MuSCAT team; the IRD Intensive team; the IRD Instrument team
The University of Tokyo; Instituto de Astrof\'{i}sica de Canarias (IAC); Astrobiology Center

In this contribution, we report the discovery of an ultracool dwarf transiting a mid-M dwarf with a period of only 10.4 hours. This object was first identified by the TESS photometric survey and subsequently characterized through ground-based observations, including multiband photometry with the MuSCAT series and radial velocity measurements with the Subaru/IRD spectrograph. The TESS and MuSCAT photometric data reveales an apparent decrease in the transit period at a rate of about 12 ms per year. If this observed period decrease is caused by orbital decay due to tidal interactions, this fact would indicate that the magnetic braking torque acting on the host star is estimated to be 10^{36} erg, which is three orders of magnitudes higher than expected for a star in the saturated regime. Alternatively, the observed period decrease could be attributed to the accereration of the binary system due to the presence of a third body. Further observations are required to unveil the underlying mechanisms that drive the period change observed in this unique system.

Theme(s): Cool Stars as Stellar Systems, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

73: Shock Fronts at the Disk-Envelope Interface of the Class 0/I Protostar L1527

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Observations of the protostar L1527 show that precursor organic molecules are enhanced in the gas phase in the inner envelope and outer disk region. Explaining why could lead to a better understanding of how these molecules are distributed in planetary formation. Models using RadChemT, a radiative transfer and astrochemistry code used to model protostars in the class 0/I phase, show that precursor organics form efficiently but remain locked on the surfaces of dust grains. This study updates RadChemT to investigate the role of accretion shocks in forming precursor organic molecules, in the region where infalling material from the envelope impacts and heats the protostellar disk. The aim is to probe whether shock heating of the dust grains can account for the desorption of these molecules into the gas phase to match observations. We use the Paris-Durham shock code, a code developed to model magnetized molecular shocks propagating in interstellar environments, to produce updated temperature and density profiles for a low-velocity (\sim 4 \text{km s}^{-1}) J-type shock propagating in a high-density medium (n_H=10^9 \text{cm}^{-3}). With the updated profiles, we use RadChemT to repeat the steps taken in the earlier research to produce new abundances and present our results.

Theme(s): New Insights into Star Formation and Evolution, Cool Stars as Stellar Systems

74: A probabilistic ML model for stellar age inference with gyrochronology

Phil Van-Lane (1,2); Joshua S. Speagle (沈佳士) (1,2,3,4); Stephanie Douglas (5)
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Gyrochronology uses a star's rotation period and location on the main sequence (MS) to predict stellar age. It is particularly useful for low mass main sequence stars, the regime in which other stellar dating methods (e.g. isochrone fitting) tend to struggle. Gyrochronology has gained popularity in recent years due to the increasing availability of photometric data, but analytical models have struggled to coherently summarize the uncertainty and intrinsic variance in the photometric time series data. Thus, we have developed a generalized machine learning-based Bayesian inference framework that captures the uncertainty and variance through a probabilistic solution. Our framework implements a normalizing flow --- a neural network-based model that optimizes the transformation of parameter distributions --- to predict rotation period distributions for stars based on their age and colour. We have successfully trained and tested the model on data from eight open clusters with promising results, indicating that a data-driven approach to gyrochronology could improve upon existing models. We have now expanded and standardized our data sample to 30 open clusters. In this talk, we will present: (i) the results of cluster age recovery testing using this new model, and (ii) the results of applying this model to fields stars.

Theme(s): The Sun and Cool Stars in the Time Domain

75: Extreme Photospheric Heating in White-Light Flares and Sunquake Sources and Search for Starquakes

Alexander Kosovichev (1); Samuel Granovsky (1); Christopher Lombardi (1); Viacheslav Sadykov (2); John Stefan (1)
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Spectro-polarimetric analysis of several X-class flares, using observations with the HMI instrument on Solar Dynamics Observatory, reveals strong emission in the core of the deep photospheric line Fe 6173A in the white-light flare kernels coinciding with the photospheric impacts that led to the excitation of helioseismic waves (sunquakes). The impacts were observed at the beginning of the flare impulsive phase, and their duration was 2-3 min. Spectro-polarimetric modeling for the recently published RADYN models with electron and proton beams showed that the line core emission could be caused by the deeply penetrating proton beams heating the lower photosphere to high temperatures. However, the observed line core emission is substantially stronger than in any of these models, indicating extreme impulsive

heating at the solar photosphere. In addition, the observed variations of the Stokes profiles reveal transient and permanent changes in the magnetic field at these impacts. More substantial photospheric impacts expected in more powerful stellar flares can excite global stellar oscillations (starquakes). We present initial evidence of such events from analysis of Kepler data.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

76: Medium Resolution Spectroscopy of Cool T-type Brown Dwarfs

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We present high-quality, medium-resolution near-infrared Gemini/GNIRS spectroscopy of a systematic sample of 30 late T-dwarfs (T6-T9). The resolution (R\approx1700) and wavelength coverage (0.8-2.4\,\mum) of our data allow us to measure and compare the metallicities and C/O ratios of field brown dwarfs, young moving group members, and wide-seperation (>500\,au) companions to solar-type stars. To do this, we have expanded the \texttt{ATMO 2020} atmosphere model grid to include non-solar metallicities and C/O ratios in the T dwarf regime. We change the C/O ratio by altering either the carbon or oxygen elemental abundances, and we find that non-solar abundances of these elements can be distinguished based on the shapes of the H- and K- bands. Fitting these models to our data we find solar C/O ratios and best-fitting parameters (T_\mathrm{eff}, \log(g), Z) broadly consistent with other analyses in the literature for the benchmark brown dwarfs GJ 570D, HD 3651B, and Ross 458C. We find consistent model-data discrepancies in the near-infrared spectra across our sample. These discrepancies are alleviated when fitting the Y, J, H and K bands individually, but the resulting best-fit parameters are inconsistent and disagree with the results from the full-spectrum.

Theme(s): Cool Stars as Stellar Systems, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

77: Methods for the detection of stellar rotation in TESS and results from the Prime mission

Isabel Colman (1); Ruth Angus (1,2); Trevor David (2); Jason Curtis (3); Soichiro Hattori (3,1); Yuxi (Lucy) Lu (1)
American Museum of Natural History; Center for Computational Astronomy, Flatiron Institute; Columbia University

Many recent advances in the study of stellar rotation have been spurred by extensive analysis of space-based data and the development of large rotation period catalogs. With high-quality time series data from the TESS mission, we have the opportunity to search and catalog the whole sky — but the challenge of detecting stellar rotation in large volumes of data requires accurate measurement and reliable automation. We present the results of a dedicated effort to detect short (13 days and under) rotation periods in individual TESS sectors. Our pipeline uses the Lomb-Scargle periodogram and autocorrelation function as tools for period detection; we then use these data to describe each sector in feature space, and measurements are vetted by a two-stage random forest classifier procedure. We searched over 430,000 individual TESS sectors to produce a high-fidelity catalog of short rotation periods for 10,909 main sequence FGKM stars in the TESS prime mission. We also present a thorough methodological study, providing insight into the application of machine learning techniques to problems in time domain stellar variability. Finally, we discuss ongoing work to extend our search for stellar rotation to longer periods in the TESS continuous viewing zones.

Theme(s): The Sun and Cool Stars in the Time Domain

78: Investigating the impact of internal heating and cooling on rotating convection

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Simulations of stellar convection are typically performed in parameter spaces orders of magnitude away from astrophysical regimes. To be astrophysically relevant, we need to be able to extrapolate simulated results into these regimes. Convection in stars is almost universally modelled using Mixing Length Theory which is “diffusion-free”: it exhibits no dependence on microphysical viscosity or conductivity. However, in typical simulations of Rayleigh-Bénard convection the heat transport is often throttled by thermal boundary layers and as such is not diffusion-free. Here, we examine simulations of convection designed to minimise the impact of these boundary layers through the use of internal heating and cooling profiles, as pioneered by Kazemi et al. 2020. We extend that work to rotating convection, and present results using both no-slip and more astrophysical free-slip boundary conditions. We find that in rotating no-slip cases the heat transport is diffusion-free. Surprisingly, we do not find the same thing in the more physical free-slip case, where we find a steeper-than-expected scaling.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

79: No Dearth for Earths: Unveiling the Earth+super-Earth Occurrence Rate in low mass M Dwarfs

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M dwarfs not only dominate the stellar population in the solar neighborhood but also host the majority of terrestrial planets in our galaxy. However, there is a gap in our understanding of the variation of planet occurrence rate with stellar mass, especially for stars with M<0.3 M_{\odot}. Some studies indicate that the terrestrial planet occurrence rate peaks at the lowest-mass stars, however, pebble accretion models predict the peak yield for stars with M~0.5 M_{\odot} with a decreasing occurrence for lower-mass hosts. Here we determine the Earth+super-Earth occurrence rate for a magnitude-limited sample of mid-to-late-M dwarfs observed with TESS. We have developed the Exoplanet Survey & Characterization Program for Earth-like Rocky planets (EXOSCAPER) pipeline for detecting multi-planetary systems using TESS lightcurves. We present 17 new candidates & validate 35 known planetary candidates within the Earth+super-Earth range. We also investigate the precision and planet detection efficiency as a function of lightcurve cadence,using 20, 120, and 200-sec data from TESS. We compute the cumulative occurrence rate = 0.24_{-0.78}^{+0.36} planets/star for a radius range of 0.2-2 R_{\earth} and periods between 0.1-7 days.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

80: Magnetism of solar-like stars through spot impact in light curves

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The mechanisms behind stellar magnetism remain an open question in stellar physics : there is a huge variety of topologies and magnetic properties and scales. The link between these properties and stellar parameters (radius, mass, age, temperature, or Rossby number) are still elusive. The photometric activity is used here as an observable to improve our understanding of spot characteristics (area, lifetime…) and link these properties to the dynamo effect which rules all these phenomena. We propose to characterize this activity using the signature of spots in the light curves, seen in the Fourier domain. For this, we revisit the model of Harvey et al. (1985) in order to take into account all the components present in the power spectra. This method allows access to two proxies of the activity : the mean spot coverage and the lifetime of the spots. After validating this model with simulated light curves, we present the results from thousands of Kepler light curves of main sequence stars used by McQuillan (2014) and Santos (2022). The results show the emergence of three different regimes of activity related to different level of spot coverage and long or short spot lifetime. These regimes are linked to different stars properties such as their rotation period, mass and the Rossby number, which can provide information about the stellar dynamo evolution.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

81: CBASS Survey: Ages for Intermediate-mass Stars from CMD Position and Metallicity

A. Smith (1); E. Nielsen (1); M. Brinjikji (2); Jennifer Patience (2); A. Peck (1); A. Ware (2); P. Young (2); J. Garani (3); J. Wang (4); R. de Rosa (5); T. Esposito (6); J. Hom (2); B. Macintosh (7), M. Liu (8); B. Bowler(9); W. Best(9); E. Softich (10); H. Gallamore (1); J. Klusmeyer (1); W. Roberson (1)
New Mexico State University; Arizona State University; Northern Arizona University; Northwestern University; European Southern Observatory; University of California Berkeley; University of California Santa Cruz; University of Hawaii; University of Texas Austin; University of California San Diego

The ongoing Companions to B/A Stars Snapshot (CBASS) survey is a direct-imaging demographics survey for wide-separation substellar companions to over 200 intermediate-mass stars in the northern sky. We present our method for calculating age posterior probability distributions for each of the target stars. By combining color-magnitude diagram position with measured vsini and [Fe/H], we derive model-based ages for the sample that are more accurate and precise than are possible from CMD position alone. We are obtaining high-resolution optical spectra from APO/ARCES for the B and A stars in the CBASS sample, and measuring of [Fe/H] and vsini for the survey sample from these spectra. We discuss how the inclusion of vsini and [Fe/H] measured from optical spectra improves the precision and accuracy of ages obtained from CMD position. Our analysis will enable robust, uniformly derived age posteriors and associated uncertainties for the sample, as well as other intermediate-mass stars. These reliable stellar sample ages are essential for direct-imaging planet search surveys, both for characterization of companions and for calculating survey completeness.

Theme(s): Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

82: Truncating the zonal jets in gas giant interiors

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Jupiter and Saturn's atmospheres are dominated by fierce zonal winds. In-situ gravity and magnetic measurements have revealed that they reach deep into the interior, but are truncated before reaching the highly electrically conducting regions. Previous 3D MHD models suggest that a direct interaction between the winds, residing in the upper convecting, non-conducting region, and the metallic hydrogen region below is not compatible with generating multiple jets reaching the higher latitudes. Christensen et al. (2020) suggested that a stably stratified layer located in this transition region may be the missing ingredient. In this study, we extend the linearised models and find that the complex dynamics governing the decay of zonal winds penetrating into a stable layer under the influence of increasing electrical conductivity can be

characterised by a single parameter which we name the MAC-number. This encapsulates the key forces acting on the flow: magnetic, Archimedean (buoyancy) and Coriolis. Applying the models to Jupiter and considering constraints imposed by the power driving the jets and their influence on the magnetic field leads to an estimated depth of the stable layer of around 2,000 km.

Theme(s): New Insights into Star Formation and Evolution, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

83: Chemical Peculiarities of Ice Grains in Dense Molecular Clouds of the Central Molecular Zone

Yewon Kang(1); Deokkeun An(1); Kris Sellgren(2); Solange V. Ramírez(3); A. C. Adwin Boogert(4); Jiwon Han(1); Sang-Il Han(1)
Ewha Womans University, Seoul, Republic of Korea ; Ohio State University, Columbus, USA; Carnegie Observatories, Pasadena, USA; University of Hawaii, Honolulu, USA

The presence of CO_2 ice absorption at 15.4 μm, indicative of ice mixed with CH_3OH, can serve as an empirical method for identifying dense clouds or dense envelopes of young stellar objects (YSOs) throughout the Milky Way and nearby galaxies. However, previous studies have found this feature to be significantly stronger toward a few red point-like objects in the Central Molecular Zone (CMZ). In this study, we investigate the chemical properties of these objects by obtaining L-band spectra using GNIRS at Gemini North, and estimate the column densities of H_2O and CH_3OH ices, and foreground extinction toward 15 objects. We confirm substantial amounts of both foreground dust and H_2O toward most of these objects, but find that the column densities of CH_3OH ices are within the range observed in dense clouds or YSOs in nearby star-forming regions. Our findings suggest that the strong CO_2 ice absorption at 15.4 μm largely results from a relatively low mixing ratio of CH_3OH in the CO_2--CH_3OH ice matrix. This further implies that the extreme gas conditions in the CMZ favor the production of CO_2 through a higher oxidation rate of CO, rather than the production of CH_3OH through its hydrogenation.

Theme(s): New Insights into Star Formation and Evolution, Cool Stars as Stellar Systems

84: TESS, Models, and Binary Mayhem

Jamie Tayar; Susan Byrom; Cooper DeVane-Prugh; Sophia Grusnis; Corin Marasco; Meir Schochet; Artemis Theodoridis
University of Florida, Gainesville, FL, USA

The combination of photometry, spectroscopy, and stellar models has allowed us to better examine what we do and don't know about stellar evolution in cool stars. I will highlight some of the work being done in my group to characterize the timescales and amplitudes of variability across stellar types, to identify oscillating subgiants and red giants in TESS data, and to estimate stellar ages. I will show the (disheartening) comparisons of well-characterized stars to

current stellar models. I will also show how we identify binary stars that could impact these comparisons, and their particular importance at low metallicity. Finally, I will show some of the ongoing efforts to improve stellar models, and to understand the complexities of translating results like these to larger contexts using machine learning.

Theme(s): New Insights into Star Formation and Evolution, The Sun and Cool Stars in the Time Domain

85: Chispas de Luz: Stellar Flare Yields with the Nancy Grace Roman Space Telescope

Guadalupe Tovar Mendoza(1);Robert F. Wilson(2);Laura D. Vega(2)(3);Allison Youngblood(2); Thomas Barclay(2); James R.A. Davenport(1)
University of Washington - Astronomy; NASA Goddard Space Flight Center; Department of Astronomy, University of Maryland, College Park

The next NASA flagship mission is the Nancy Grace Roman Space Telescope (Roman), which is expected to launch in 2026. One of Roman's core community surveys, the Galactic Bulge Survey (GBTDS) will collect precise, time-series photometric data for over 100 million stars. Flares are a key observable for understanding stellar magnetic, and the GBTDS will be the first survey of its kind to focus on an older stellar population. Here we consider one season of Roman observations and assess the stellar flare yields for G, K, and M stars in the galactic bulge. To assess types of flares to which Roman will be sensitive, we run 10,000 simulations each for G, K, and M stars which include realistic noise properties and injected stellar flares. Furthermore, we compare two read-out strategies: a logarithmic case and one which preserves all read frames to study which maximizes the Roman flare science return. We are able to recover flares on 1 percent of G stars, 0.3 percent of K stars, and 10 percent of M stars.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

86: Searching for stellar CMEs in the Praesepe and Pleiades clusters

K. Vida (1); R. Roettenbacher (2); B. Seli (1,3); A. Görgei (1,3); L. Kriskovics (1); Zs. Kővári (1); K. Oláh (1)
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On the Sun, the energetic, erupting phenomena of flares and coronal mass ejections (CMEs) often occur together. While space-based photometry has revealed frequent white-light flares for vast numbers of stars, only a handful of coronal mass ejections have been detected. Space-based photometry reveals the timing and detailed structure of flares. To detect CME signatures, however, optical spectroscopy is essential, as the ejected plasma can be detected by Doppler-shifted emission bumps in the Balmer-regions. We present a dedicated

ground-based multi-object spectroscopic observations of the young, nearby Praesepe (600 Gyr) and Pleiades (135 Gyr) clusters to detect CMEs and flares parallel with the observations of Praesepe by the TESS satellite. During the 10 days of overlapping observations, we did not find any obvious signs of CMEs or flares in the Halpha region.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

87: Absolute radial velocity shifts for sunspots over magnetic field and limb angles

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Georg-August-Universität Göttingen, Germany

Mitigation of stellar activity is the main bottleneck we currently face within low-mass exoplanet detection and characterisation. Solar data is often used as a basis for testing methods for reducing the impact of stellar signals on exoplanets' radial velocities, however we are missing high resolution observations of solar activity features that would allow us to quantify separate activity components. I present sunspot spectra and their absolute radial velocities with respect to the quiet sun. These spectra are obtained over a 4000 Å range with a Fourier Transform Spectrograph that achieves 10 cm/s wavelength precision (R~700,000 at 6000 Å). They are taken at various magnetic field strengths and limb angles, as part of a series of observations across these two variables. We also present preliminary spectra of faculae, which until now have been entirely missing from stellar mitigation models. We demonstrate how these sunspot and faculae data can be used to quantify the variation in convective blueshifts from magnetic fields and centre-to-limb variation, across solar-like stars. This is crucial for treating stellar activity as signals rather than noise in exoplanet models and enables the community to characterise stellar activity on a level which we have not previously had access to, facilitating more accurate determinations of low mass exoplanet properties and atmospheres.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

88: X-ray activity & rotation in the 10pc M dwarf sample: From superflare to hardly there

B. Stelzer (1), M. Caramazza (1), St. Raetz (1), E. Magaudda (1), C. Argiroffi (2), M. Güdel (3), S. Orlando (4), K. Poppenhäger (5), M. Hassan (1)
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Volume-complete samples are key to characterizing stellar populations. We have set out to constrain the activity and rotation rates of all 150 early-M dwarf stars within 10pc of the Sun (from Reyle et al. 2021). Hereby, we uncover the full spread that such stars can exhibit, which we find to span three orders of magnitude both in X-ray brightness and rotation period. At the extremes, we have identified a superflare on AD Leo, that was shown to be 10 000 times more energetic than a typical solar flare, and a star with no persistent X-ray emission, consistent with the properties of a solar coronal hole. To calibrate the M dwarf X-ray activity on our Sun, we use the Sun-as-an-Xray-star approach, transforming solar Yohkoh observations to stellar-like data. Our study is based on a dedicated deep XMM-Newton survey complementing archival X-ray data and the recent eROSITA half-sky surveys, as well as newly determined TESS rotation periods combined with published rotation data. We also derive optical flare rates from TESS light curves. We find the majority of 10pc M dwarfs to be low-activity and slowly rotating stars, in contrast to flux-limited samples of M dwarfs where the majority are ‘saturated’. This underlines the importance of volume-limited studies for our understanding of biases in larger but incomplete samples.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

89: The impact of companions on the rotation of Praesepe early M dwarfs

S. T. Douglas (1); J. Sofair (1); A. L. Kraus (2); M. Wood (3); A. Mann (4); N. Gosnell (5); T. Dupuy (6)
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Binary companions likely affect stellar rotational evolution via tides (for close binaries) and disruption of the protoplanetary disk (for binary semimajor axes out to at least 5 to 80 AU). However, models of angular momentum evolution assume that all stars are single, and tidal models for solar-type stars cannot explain the handful of existing observations. Binary surveys in open clusters are woefully incomplete, particularly for K and M stars and stars with measured rotation periods. We have surveyed 51 M0-M1 members of the Praesepe open cluster using adaptive optics and non-redundant aperture masking at Keck II. All of our targets already have rotation period measurements. We detect 19 companions and 5 probable chance alignments from our core sample. We then combine detection limits from additional AO data, WIYN/Hydra radial velocities, and Gaia astrometry to robustly determine the impact of companions on the rotation distribution in Praesepe.

Theme(s): Cool Stars as Stellar Systems

90: Turbospectrum NLTE: A New Version of Turbospectrum Capable of Non-LTE Radiative Transfer

Jeffrey Gerber (1); Nicholas Storm (2); Bertrand Plez (3); Maria Bergemann (2); Richard Hoppe (2); Ulrike Heiter (4); Terese Olander (4)
(1) Purdue University; (2) Max Planck Institute for Astronomy; (3) LUPM, Université de Montpellier; (4) Uppsala University

As the number of spectroscopic stellar surveys continues to increase, accurate physical models of observed stellar spectra are more important than ever to derive abundances and stellar

parameters. Non-Local Thermodynamic Equilibrium (NLTE) radiative transfer models are often needed to accurately model certain lines in the optical region of the electromagnetic spectrum, however, it is often difficult to use models with NLTE due to the computational resources and time required to calculate these models. In an effort to make spectra models with NLTE more accessible, we have updated a radiative transfer code, Turbospectrum, to be able to compute synthetic spectral lines of multiple elements, simultaneously, in NLTE. We present the updated version of Turbospectrum, and a sample analysis of metallicities and calcium abundances in Gaia FGK benchmark stars using both MARCS 1D model atmospheres and averaged 3D radiation-hydrodynamics simulations of stellar surface convection. Our analysis also makes use of TSFitPy, a Python wrapper that is able to run Turbospectrum for any input parameters as well as automatically fit synthetic spectral lines to observed line profiles and generate grids of synthetic spectra. We also show some recent results in the literature that make use of Turbospectrum and TSFitPy. Both Turbospectrum and TSFitPy are publicly available as well as grids of NLTE departure coefficients of H, O, Na, Mg, Al, Si, Ca, Ti, Mn, Fe, Co, Ni, Sr, Y, Ba, and Eu.

Theme(s): Milky Way-scale Science and Big Data, Cool Stars as Stellar Systems

91: How old (or young) is famous host-star HD 110067, really?

M.Loupien (1) ; K-P.Schröder (2) ; F.Rosas Portilla (3) ; D.Jack (4)
Universidad of Guanajuato ; Université de Bordeaux

This 8.4 mag K0V star in Coma Ber, only 30pc away, has recently been discovered to host a 6-tuple (at least) planetary system in stable resonances, see Luque et al. (2023, Nature). The same authors claim an unusually large age of this system of 8\pm 4 Gyrs. However, by the nature of the respective evolution track, which runs in parallel to the ZAMS for the first \sim5 Gyrs, this is highly uncertain. We therefore looked at the stellar activity (emission in Ca II optical UV doublet) as an additional age parameter, using the TIGRE facility in Guanajuato, MEX, and compare HD 110067 with a well-observed twin star, sigma Draconis. Remarkably, HD 110067 is a very active star, with S_{MWO} = 0.32 (consistently in two pointings 9 days apart), while sigma Dra (standard K0V star with a lithium age of 3 Gyrs) varies between S_{MWO} = 0.17 and 0.24. In this poster we compare these two stars in more detail and with plausible evolution models, in order to verify a possibly young age of HD 110067. An alternative explanation of the unusually strong chromospheric emission could be an intense interaction between the innermost planet and its host-star.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

92: Magnetic Radio Bursts from an Ultracool Dwarf Binary Detected Using VLITE

Michele L. Silverstein, Tracy E. Clarke, Wendy M. Peters, Emil J. Polisensky, Jordan M. Stone
U.S. Naval Research Laboratory, Washington D.C., USA

Magnetically driven phenomena such as flaring events, aurorae, and (yet-undiscovered) star-planet interaction lead ultracool dwarfs to emit in radio frequencies. Despite decades of scrutiny, a comprehensive physical understanding of their radio emission at different frequencies, timescales, polarization, and coherence remains elusive, spurring on additional study of these complex objects. The VLA Low-band Ionosphere and Transient Experiment (VLITE) is a commensal survey attached to the Very Large Array, operating at 340 MHz. This frequency regime is relatively unprobed in ultracool dwarf studies. Because VLITE takes observations simultaneous with VLA observations, the survey spans the majority of the sky north of Dec = -40 deg, with coverage ranging from 30 seconds to 8 hours. Here we highlight emission discovered from an ultracool dwarf binary on the timescale of hours, demonstrating the potential of the VLITE system and kicking off a larger survey of thousands of fully convective M dwarfs in the solar neighborhood.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

93: On the stability of toroidal magnetic fields in radiative stellar interiors

Domenico G. Meduri (1,2); R. Arlt (1); A. Bonanno (2); G. Licciardello (2)
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The stability of toroidal magnetic fields in radiative stellar interiors remains a major open issue to advance our understanding of the rotational and chemical evolution of low-mass stars. We perform 3D direct numerical simulations in a spherical geometry to examine the Tayler instability, a kink-type instability of purely toroidal fields expected to occur in stably stratified stellar interiors. The simulations are novel in that they consider a consistent background state derived from magnetohydrostatic equilibrium and explore the combined effect of gravity and thermal diffusion, as well as of fluid viscosity and magnetic resistivity. We trace the entire evolution of the instability from the linear to the nonlinear phase. Our simulations show that stable stratification and magnetic diffusivity can inhibit unstable modes, in agreement with linear stability analysis predictions by Bonanno & Urpin (2012). This suggests that toroidal fields in radiative stellar interiors may be only partially affected by Tayler instability and that the associated turbulent transport is lower than expected. These results may have implications for explaining the solid body rotation of the solar radiative core and the origin of the magnetic fields recently observed in red giant cores.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

Wednesday-Friday Posters

1: The Significance of Stellar Flares on Exoplanet Atmospheres and Habitability

L. Huseby (1); T. Barman (1); S. Peacock (2, 3)
University of Arizona, Lunar & Planetary Laboratory, Tucson, AZ; University of Maryland, Baltimore County, Baltimore, MD; NASA Goddard Space Flight Center, Greenbelt, MD

Stellar flaring is an important topic of concern for estimating the true habitability of planets around cool stars, where the habitable zone is in close proximity to high fluxes that are potentially harmful for the orbiting planets. Flares occur when magnetic reconnection events heat localized regions of a stellar surface resulting in elevated fluxes across most wavelengths, including the Extreme-Ultraviolet (EUV, 100-912 Å) region. Unfortunately, the current lack of EUV-capable observatories and obscuring effects by the ISM make direct observations of host star EUV fluxes difficult. We use the PHOENIX atmosphere code to model the EUV region during quiescent and flaring events using GALEX and EUVE photometry and archival HST Ultraviolet data as guidance. Our approach of tuning temperature structures and using non-LTE radiative transfer is similar to that previously used to model Solar flares and our models have revealed subtle differences between quiescent and flare model predictions that may be hidden by lower-resolution models or broadband-integrated flux comparisons. Here we quantify EUV flux changes during flaring events and investigate specific emission lines to determine if flares are an important contributor to long term EUV-driven mass loss and their potential impact when modeling exoplanet atmospheres.

Theme(s): Cool Stars as Stellar Systems

2: Evolution of Flaring Activity with the \beta Pictoris and AB Doradus Moving Groups

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Stellar flares are panchromatic, high energy (>10^{30} ergs) events which occur as a result of magnetic reconnection. For low mass stars, these events serve as a significant source of excess near ultraviolet and X-ray radiation compared to the low temperature blackbody contribution. The magnetic activity for low mass stars is essential context for understanding how the radiation environment around the star and how it has evolved over the epochs of planet formation. We present a preliminary analysis of the flaring behaviors of low mass stars within the \beta Pictoris (\sim 24 Myr) and AB Doradus (\sim 150 Myr) Moving Groups. As nearby and well populated moving groups, the direct comparison of their activity offers insight into the stellar distribution within the well-observed activity ‘saturated’ regime with short rotation periods. All data used in this study are from two minute cadence observations by the Transiting Exoplanet Survey Satellite. We extract flare properties using a blend of canonical outlier detection and morphology-informed machine learning techniques. The optical cumulative flare rates and

energies from these stars are shown with results from broader flare studies to explore this sample's independence from field stars. Additionally, we present the flare properties of these stars as a function of physical characteristics including spectral type and rotation. This analysis also provides some introductory understanding of flares evolve with age.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

3: Investigating the Spectroscopic Time Variability of Ultra-Cool Brown Dwarfs

Nicole Wallack (1); Julie Inglis (2); Heather Knutson (2); Jerry Xuan (3); Yapeng Zhang (3)
Earth and Planets Laboratory, Carnegie Institution for Science, Washington, DC, USA; Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, USA; Department of Astronomy, California Institute of Technology, Pasadena, USA

Ultra-cool brown dwarfs offer a unique opportunity to explore the chemistry and cloud properties of cold substellar atmospheres. These objects provide insights into the physics and chemistry that govern cool hydrogen-dominated atmospheres in a way that is not yet possible for the majority of exoplanets due to the lower SNR and spectral resolution generally accessible for exoplanets at comparable temperatures. In particular, the 3D structure of such atmospheres, the presence and variability of clouds, and local changes in temperature structures are all possible to investigate using ground-based spectroscopic observations of ultra-cool brown dwarfs. Here, I present initial results from an ongoing multi-year, time-resolved, low-resolution (R~300) spectroscopic survey of late-T dwarfs using Magellan I/FIRE, motivated by the question of whether variability is the cause of the ubiquitous mismatches between observations of these objects and self-consistent forward models. To date, we have observed eight late-T dwarfs for multiple hours each, acquiring at least ten high SNR low-resolution spectra per target to get adequate time sampling over each object's rotation period. We then performed atmospheric retrievals on each of the time-sampled spectra in order to place constraints on the atmospheric composition, temperature structure, and presence of clouds with rotation to better understand the 3D nature of cool substellar atmospheres, which can inform our models of these objects.

Theme(s): Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

4: Fine Structures of Radio Bursts from Flare Star AD Leo with FAST Observations

J. Zhang (1); H. Tian (1); P. Zarka (2,3); C. K. Louis (4); H. Lu (1); D. Gao (5); X. Sun (6); S. Yu (7); B. Chen (7); X. Cheng (8,9,10); K. Wang (11)
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Aurora-like radio emission has been detected from many nearby M-dwarfs. It is presently unclear if the acceleration mechanism powering the emission is coronal (i.e. Sun-like) or magnetospheric (i.e. Jupiter-like). Millisecond-timescale structures in the radio emission hold clues to identifying the emission mechanism, but they have been rarely detected. In this talk, I will report the high time-resolution observations of a flare star AD Leo with the Five-hundred-meter Aperture Spherical radio Telescope. The data, taken over a 2-day campaign, shows numerous millisecond timescale structures (sub-bursts). Sub-bursts on the first day display stripe-like shapes with nearly uniform frequency drift rates, which are possibly stellar analogs to Jovian S-bursts. Sub-bursts on the second day, however, reveal a different blob-like shape with random occurrence patterns and are akin to solar radio spikes. Our observations provide evidence to support that radio emission from AD Leo is driven by electron cyclotron maser instability, which may be powered by interactions with a close-in exoplanet or a persistent pool of trapped high energy charges produced by numerous ongoing stellar flares.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

5: Observational constraints on the post-outburst evolution of FU Ori objects and their outflows

A. S. Carvalho, L. A. Hillenbrand
California Institute of Technology

FU Ori objects are a class of young stars currently undergoing prolonged, extreme accretion outbursts, with accretion rates 1000-10000 times greater than those of Classical T Tauri Stars. Although the sample of FU Ori objects remains relatively small, it has grown exponentially in the last few decades. The age of all sky surveys has enabled more rapid follow-up of the most recent outburst events and better characterization of the progenitors than was possible before. The post-outburst evolution of two FU Ori objects in particular, HBC 722 and V960 Mon, has been closely monitored with multiband photometry and low- and high-resolution multiband spectroscopy. I will describe how the rich datasets collected on these two objects enable us to place meaningful constraints on the physical parameters of the disks, like $\dot{M}$, by measuring (via models) the disk’s thermal properties (Tinner and Touter) and physical properties (Rinner and Router). I will also discuss how these properties change over the first few years of the outbursts.

I will then compare the evolution of the systems to existing models of disk instabilities to constrain which instabilities are active in the two. I will also discuss how we can connect the differences between the two objects to their distinct lightcurves and potentially generalize the lessons learned from HBC 722 and V960 Mon.

Theme(s): New Insights into Star Formation and Evolution, The Sun and Cool Stars in the Time Domain

6: The Demographics of Planet Formation and Survival in Binary Star Systems

Adam Kraus
The University of Texas at Austin

The majority of stars form with a binary companion, and those binary systems appear to be hostile sites for planet formation and survival. The outcome of binary star formation is strongly mass-dependent, suggesting that the impact on planetary systems could also vary dramatically, especially for the low-mass stars that are the best opportunity for finding other Earths. When a binary companion is found on solar-system scales, the planet occurrence is suppressed by a factor of ~3, but nonetheless even some very dynamically active binary systems do host surviving planets. The impact of wide or low-mass binary companions appears to be less severe, but has not been fully quantified due to small survey samples and biases in both the Kepler target selection and the binary census. The dependence of planet survival on primary star mass, companion mass, and binary semi-major axis will distinguish which processes are most important in either forestalling planet formation (via disk dispersal and planetesimal stirring) or destroying planets after they form (via secular orbital evolution). I will present a multiplicity census of the full Kepler planet-host population (~3000 planet hosts), combined with an updated model of the biases for and against binary stars in the Kepler target selection. This survey expands past statistical samples by an order of magnitude, allowing for a detailed assessment of which stellar and binary features correlate with planet destruction/survival.

Theme(s): Cool Stars as Stellar Systems

7: Li-rich stars and their ^6Li/^7Li isotope ratio

T. Sitnova
Institute of Astronomy INASAN, Moscow, Russia

Stellar lithium abundances together with the ^6Li/^7Li isotope ratios offer valuable observational constraints on the origin and evolution of lithium - a chemical element with the most complicated formation history. We introduce and validate a novel approach for lithium abundance and isotope ratio determination. In stars with well-determined parameters and high-quality spectra, we analyse the Li I subordinate line at 6103 A and the resonance line Li I 6707 A, considering deviations from the local thermodynamic equilibrium (non-LTE effects). The Li I 6103 A line is weak and immune to the adopted isotope ratio, we use this line for lithium abundance determination. In contrast, the resonance line Li I 6707 A is sensitive to the assumed isotope ratio, and different abundances are obtained when assuming different ^6Li/^7Li. Additionally, we account for 3D effects using the literature data. We analyse Li-rich stars with diverse atmospheric parameters, from turn-off stars to red giants, and determine their Li abundances and ^6Li/^7Li ratios. In 1D non-LTE, the presence of ^6Li remains negligible within a 2-sigma error in our sample stars. However, when accounting for 3D effects, a considerable amount of ^6Li is observed, posing a challenging explanation. Expanding our method to stars with distinct chemical compositions, evolutionary stages, activity levels, binarity, etc., makes it a promising tool for providing insight on mechanisms of ^6Li and ^7Li synthesis.

Theme(s): New Insights into Star Formation and Evolution, Cool Stars as Stellar Systems

8: A New Sample for Testing Stellar Evolution: Wide Binaries

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Short-period eclipsing binaries with orbital periods of less than a few months are the easiest way to obtain precise stellar masses and radii to test stellar evolution models. However, solar to low-mass stars in these systems often have radii larger than model predictions by about 10 percent, commonly known as "the radius inflation problem." Some ideas suggest the discrepancy could be the sample; eclipsing stars can have tidally locked components that induce rapid rotations and chromospheric activity, inflating the radii. However, the problem could be with the models themselves, as most models approximate complicated input physics with simple 1-dimensional approximations. We propose to tackle the radius inflation problem by studying "wide" binaries that represent single stars better and are free from the bias of tidal locking. We present a sample of solar to low-mass stars in 14 systems within 12 pc and have orbital periods from almost 1 to several hundred years. Our key objective is to measure precise (1-2 percent) angular diameters for this sample using the CHARA Array, the world's highest-resolution optical/infrared interferometer. Currently, only 53 percent of the sample has precise dynamical masses or mass constraints. As radial velocity and orbital monitoring programs continue to provide and constrain their masses, this sample will consist of the nearest single-like main sequence stars that will serve as humankind's "second best" example of how stars work.

Theme(s): Cool Stars as Stellar Systems

9: Leveraging host star abundance ratios to constrain directly imaged planet formation and structure

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Interpreting the atmospheric abundances of planets in the context of their formation requires us to compare them to the host star abundances. Several active projects are measuring the abundance ratios (especially C/O) of directly imaged planets with ground-based telescopes, as well as programs using NIRSpec and MIRI on JWST. However, most of these directly imaged planet host stars are of spectral type B, A, and F, which are usually fast rotators (vsini > 30km/s), making their atmospheric characterization particularly challenging. Not only do most of the host stars have missing or poorly constrained abundances, but the existing abundance measurements are obtained using different data sets and analysis techniques. We are currently developing a library of these host stars using a uniform data set and analysis techniques to measure the stellar properties and abundances of 15 elements (including C, O, and S). We present the analysis procedure and the results of an initial set of five host stars. It features the host stars of some extremely well-known systems like HR 8799, 51 Eri, and HD 206893, among others. Measuring the C/S, O/S, and C/O ratios allows us to better constrain planet formation, especially once planetary sulfur abundances are measured for the first time using JWST. The measurement of other elemental ratios (like Fe/Si and Mg/Si) for the host stars could also be used to model cloud composition as well as the deep interior structure of these gaseous companions.

Theme(s): Cool Stars as Stellar Systems, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

10: Revealing starspots on binary stars with eclipse mapping

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In eclipsing binary systems with magnetically active components, the eclipsing star can occult starspots, causing light curve modulation at the bottom of the eclipses. Using TESS data, we compiled a catalog of 29 binaries with K giant primaries and obvious spot transits, and used the modulated eclipses to map the spot pattern of the stars.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

11: Astrometric Accelerations as Dynamical Beacons: Imaging Planets Around Young Accelerating Stars

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The University of Texas at Austin, Austin, United States; Johns Hopkins University, Baltimore, United States; University of Virginia, Charlottesville, United States; University of Warwick, Coventry, United Kingdom; Space Telescope Science Institute, Baltimore, United States; University of Edinburgh, Edinburgh, United Kingdom; Amherst College, Amherst, United States; American Museum of Natural History, New York, United States; University of California, Santa Cruz, Santa Cruz, United States; University of Notre Dame, South Bend, United States; California Institute of Technology, Pasadena, United States; University of California, San Diego, La Jolla, United States;

Directly imaged planets and brown dwarfs are key tools for studying the formation, evolution, and atmospheric physics of substellar objects. Previous imaging campaigns have been limited by the low occurrence rate of long-period giant planets. One approach to overcome this is to use astrometric accelerations to create a dynamically informed target sample by identifying stars with small proper motion changes between Hipparcos and Gaia that point to the presence of unseen substellar companions. We are using this strategy to carry out a high-contrast imaging survey of the accelerating stars most likely to harbor long-period giant planets. Here, I will present an overview of our program and exciting discoveries including the lowest-mass directly imaged planet with a dynamical mass measurement, AF Lep b. I will also share new results from follow-up observations to characterize the atmosphere of AF Lep b with JWST/NIRCam imaging.

Theme(s): Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

12: Can \textit{Kepler} See Faculae?

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We investigate how faculae are manifested in the precision broad-band light curves gathered by \textit{Kepler} from solar-type stars. We show the purely facular signal could easily reveal their rotation periods, but for stars like the Sun the accuracy of the inferred period from observations is kept low by short-lived starspots. We find that faculae would have to be twice as bright to overcome this problem. One way to increase the influence of real faculae is to use bluer bandpasses. Otherwise faculae do not affect broad-band differential light curves in a measurable way, and so are probably not explanatory of other effects found in \textit{Kepler} light curves. This is even more true for TESS differential light curves.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

13: Using Precise Fundamental Properties of 1000+ Ultracool Objects to Validate Model Atmospheres

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Atmospheric models form a critical bridge between the observable parameters (colors, magnitudes, and spectra) of imaged exoplanets and brown dwarfs and their physical properties (e.g., temperatures, gravities, and radii). Studies focusing on individual targets or small samples of interest show that systematic uncertainties in this model-based approach limit how reliably we can characterize substellar objects. Here, we use a large-scale homogenous analysis of brown dwarfs and planetary-mass objects to investigate the strengths and weaknesses of current model atmospheres. Leveraging recent advances in high-precision parallax measurements, we derive the bolometric luminosities of 1000+ ultracool dwarfs by directly integrating flux-calibrated optical to mid-infrared spectral energy distributions constructed entirely using the newly released UltracoolSheet v2.0. Coupling the derived bolometric luminosities and uniformly analyzed age estimates of these objects with evolutionary models, we estimate the masses, radii, and effective temperatures of substellar objects across the M, L, and T spectral sequence. This work increases the sample size of ultracool dwarfs with empirical fundamental physical parameters by a factor of ~5. Our large sample enables a detailed characterization of atmospheric model systematics as a function of spectral type and position in the near-infrared color–magnitude diagram.

Theme(s): Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

14: Effectiveness of multi-band simultaneous monitoring for starspot characterization on cool dwarfs

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Atmospheric characterization of exoplanets via transmission spectroscopy requires careful consideration of starspots on their host stars. The effect of spots poses significant challenges, particularly for planetary systems around cool (M, K-) dwarfs, where spot properties remain incompletely understood. The aim of our research was to explore the spot characteristics of the young M-dwarf K2-25 and assess their impact on transit observations of the sub-Neptune K2-25b. We conducted simultaneous multi-band monitoring observations of stellar brightness variability using ground-based telescopes and TESS. We found that the temperature difference

between the spots and photosphere of K2-25 is <190K and the spot covering fraction is <61% (2σ). These results suggest that spots could distort the transmission spectrum of K2-25b by as much as ~100ppm amplitude, corresponding to the JWST/NIRSpec precision on the target. We have demonstrated that simultaneous multi-band observations can effectively constrain spot properties of M-dwarfs with sufficient precision to be considered in transmission spectroscopy of the planetary atmospheres. Furthermore, this method holds promise for broader application across a diverse range of stars to elucidate general spot characteristics. In our presentation, we will showcase the effectiveness of this method, including recent findings derived from its application to the cool dwarfs within young stellar clusters.

Theme(s): The Sun and Cool Stars in the Time Domain

15: A decade of chromospheric activity monitoring with TIGRE (Mexico)

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University of Guanajuato, Guanajuato, Mexico; Hamburg Observatory, University of Hamburg, Germany.

The robotic 1.2 m telescope TIGRE, the former Hamburg Robotic Telescope, has been operating in Guanajuato (Mexico) since the summer of 2013. In the meantime, its R = 20,000 HEROS echelle spectrograph has produced a data trove of an estimated 70,000 spectra, covering (in two channels) the wide range of 380 to 870 nm, including the chromospheric emissions in Ca II (UV doublet and IR triplet) and H-alpha. Among other projects of time-critical observations, as on superluminous binary stars with colliding winds, novae, or giant chromospheric eclipses, a decade of chromospheric activity monitoring of over 100 main sequence stars and 40 giants has now been accomplished, providing a homogenous record. Since most of these stars were already covered in the 1970s and 1980s by the Mount Wilson project, and by using their same calibration star sample and S-index, we can also compare with those historic Mount Wilson data and gain insight into long-term changes in magnetic activity on a timescale of half a century. We here give a few illustrating examples.

Theme(s): nan

16: Using Statistical Methods to Identify Hidden Visual Binaries in Gaia DR3

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Vanderbilt University; Georgia State University; Gemini Observatory/NSF's NOIRLab

In the Gaia era, resolved binaries have never been easier to detect via. common parallaxes/proper motions. However, Gaia astrometry is not always available for both components at < 2.5", meaning a significant number of nearby binaries are hiding in the Gaia dataset. To this end, we developed a statistical method to identify likely visual binaries that

doesn't rely on astrometry. This method utilizes differing PSF sizes, where at < 2.5" two stars may be unresolved in 2MASS but resolved by Gaia. Here, the unresolved 2MASS source associated with the resolved Gaia sources has a predictable excess in the J-band that depends on the \Delta G from Gaia. This relationship between J-band excess and \Delta G differs for chance alignments, as compared to true binaries, when various other parameters are considered, allowing the chance likelihood of any candidate pair to be quantified. We evaluate this for pairs within 200 pc, resulting in a catalog of 68,725 likely binaries. We then obtained Gemini speckle observations of 16 of these systems. With the Gaia and speckle positions, we assess the likelihood of the systems being true binaries vs. chance alignments based on their apparent motion. We find all 16 systems are true binaries if the total average measurement error is ~4%. This estimate of the error for close separation binaries will be crucial when examining time series data in Gaia DR4 and will facilitate more robust error estimates of mass determinations for these systems.

Theme(s): Milky Way-scale Science and Big Data, Cool Stars as Stellar Systems

17: Localizing a giant flare on a young scallop-shell star

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Scallop-shell stars are rapidly rotating M dwarfs in young open clusters and star-forming regions with complex and strictly periodic photometric modulation. The cause for this modulation is poorly understood. Some of the stars show changes in their modulation patterns after strong flares, indicating interaction with the structures causing the modulation. We present our preliminary results of TIC 206544316, a scallop-shell star observed by the Transiting Exoplanet Survey Satellite, which displayed a long-duration giant flare modulated by the star's fast rotation. The appearance of the modulation was permanently altered after the flare. We used middle- and high-resolution spectra from Gaia RVS and the MIKE spectrograph at the Magellan Telescopes at Las Campanas Observatory in Chile to constrain the inclination of the stellar rotation axis using the cross-correlation method and Bayesian framework from Masuda and Winn. By combining information from the stellar inclination and the structure of the flare lightcurve, we found that the flare is a low-latitude flare at \theta= 11.38^{+2.2}_{-0.99} degrees, low enough to interact with equatorial material. This interaction could be the cause of the observed modulation change, aligning with theories that scallop-shell stars involve material near the equator. Our work shows that flares can be powerful probes into the surroundings of potentially planet-hosting young M dwarfs.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

18: How planets help us understand stars: a hierarchical model for mapping stellar surfaces.

Sabina Sagynbayeva (1,2); Will M. Farr (1,2)

Stony Brook University; Flatiron Institute.

If we wish to measure the properties of exoplanet atmospheres, we need to understand contamination by stellar magnetic activity. If we aim to detect small planets orbiting Sun-like stars, we must remove astrophysical artifacts arising from stellar variability due to starspots. Therefore, understanding starspots is fundamental and imminent for the ongoing space mission JWST, which will characterize tens to hundreds of exoplanet atmospheres around stars exhibiting strong variability. Planets can aid in our understanding of stars, and vice versa. We have developed a hierarchical Bayesian model using Gaussian processes to map the evolving surfaces of exoplanet-hosting stars based solely on time-series photometry from the Kepler and TESS telescopes. The model treats starspot properties as random samples from a parent distribution governing physical starspot characteristics to predict typical spot sizes, active latitudes, and timescales rather than properties of individual spots. Because planets can cross spots and their signatures are observed in the in-transit data, and given the abundance of transits in Kepler and TESS data, exoplanet-hosting stars represent the best candidates for variability studies. Our model is capable of inferring not only the starspot parameters but also the stellar orbital parameters such as obliquities and inclinations.

Theme(s): The Sun and Cool Stars in the Time Domain

19: Characterizing Accretion Mechanisms across the Brown Dwarf Regime

Sarah Betti (1); Katherine Follette (2); Kimberly Ward-Duong (3); Ann Peck (4); Yuhiko Aoyama (5); Jeffrey Bary (6); Beck Dacus (7); Suzan Edwards (3); Gabriel-Dominique Marleau (8); Khalid Mohamed (9); Joseph Palmo (10); Cailin Plunkett (10); Connor Robinson (11); and Huichen Wang (2)
Space Telescope Science Institute, Baltimore, MD, USA; Amherst College, Amherst MA, USA; Smith College, Northampton, MA, USA; New Mexico State University, Las Cruces, NM USA; Kavli Institute for Astronomy and Astrophysics, Peking University, Beijing, China; Colgate University, Hamilton, NY, USA; University of California San Diego, La Jolla, CA, USA; Institut für Astronomie und Astrophysik, Universität Tübingen, Tübingen, Germany; Boston University, Boston, MA, USA; Massachusetts Institute of Technology, Cambridge, MA, USA; Alfred University, Alfred, NY, USA

From the first detection of brown dwarfs in the throes of formation to recent discoveries of accreting protoplanets, we have relied on assumed parallels between stellar and substellar accretion to interpret our measurements. However, our theoretical understanding of planet formation predicts differences between stellar and protoplanet accretion, raising concerns about whether these parallels are valid. Brown dwarfs (BDs) provide a critical bridge between the stellar and planetary domains; understanding the mechanisms responsible for their accretion is key to determining their formation, and that which governs both low mass star and protoplanet formation. In this talk, I will discuss my work to disentangle systematic effects from variation in true physical properties using the Comprehensive Archive of Substellar and Planetary Accretion Rates (CASPAR), a compilation of >1000 systematically rederived accretion rates from ~800

stars, BDs, and protoplanets. I will demonstrate that BDs show population-level trends in their accretion rates that depend strongly on both age and mass, and which makes them distinct from stellar analogues. I will then discuss the consequences that applying stellar accretion physics can have on measuring substellar accretion rates, how this affects the large scatter seen in accretion rate at individual masses, and how differences in accretion can point to a potentially separate path for brown dwarf formation.

Theme(s): Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

20: Dynamical coupling of the dynamo and the wind: Towards a realistic stellar cycle

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AIM, CEA Saclay, France

Magnetic fields in stars are essential as a key component of the star dynamics, but also as they shape the astrosphere. However, there are extremely few models that are able to model both the interior of a star and its environment, as they include different challenging physical ingredients. This means that very few models can tackle the mechanism of generation of the magnetic through the dynamo effect, and their consistent evolution in the star environment as it is influenced by its interaction with the solar wind. We present here results from one of the first dynamical model able to couple the dynamo and the solar wind. We have implemented an alpha-Omega mean-field dynamo in the PLUTO code in 2.5D, and then coupled it to a spherical polytropic wind model via an interface composed of four grid layers with dedicated boundary conditions. Here we present an update of our models, with new efforts to include a greater diversity of stellar magnetic fields. To do so, we have implemented a Babcock-Leighton dynamo which has been validated through a benchmark, and we have started to couple it with the solar wind. We discuss the difficulty of controlling the amplitude of the surface magnetic field, and present preliminary results regarding the simulation of the wind for anti-solar rotation profiles.

Theme(s): New Insights into Star Formation and Evolution, Cool Stars as Stellar Systems

21: On Earth's habitability over the Sun's main-sequence history

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The aim of this study is to analyse the Earth habitability with respect to the direct exposition of the Earth atmosphere to the solar wind (SW) along the Sun's evolution on the main sequence including the realistic evolution of the space weather conditions and the Earth magnetic field. The MHD code PLUTO in spherical coordinates is applied to perform parametric studies with respect to the SW dynamic pressure and the interplanetary magnetic field intensity for different Earth magnetic field configurations. Quiet space weather conditions may not impact the Earth habitability. On the other hand, the impact of interplanetary coronal mass ejections (ICME) could lead to the erosion of the primary Earth atmosphere during the Hadean eon. A dipolar field of 30 μT is strong enough to shield the Earth from the Eo-Archean age as well as 15 and 5 μT dipolar fields from the Meso-Archean and Meso-Proterozoic, respectively. Multipolar weak field period during the Meso-Proterozoic age may not be a threat for ICME-like space weather conditions if the field intensity is at least 15 μT and the ratio between the quadrupolar (Q) and dipolar (D) coefficients is Q/D ≤ 0.5. By contrast, the Earth habitability in the Phanerozoic eon (including the present time) can be hampered during multipolar low field periods with a strength of 5 μT and Q/D ≥ 0.5 associated with geomagnetic reversals. Consequently, the effect of the SW should be considered as a possible driver of Earth's habitability.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

22: Plasma Sheath Electric Fields and Jets of the Sun and Solar Wind

C. Fred. Driscoll
UCSD

A model of electric energization of the Solar Wind and Corona is developed, including electro-magnetic (EM) particle effects precluded by traditional magneto-hydro (MHD) assumptions. This model gives quantitative agreement with the 4.keV maximum proton Wind energy measured by Ulysses outside the ecliptic plane. Using standard 1-D radial Solar models for particle density and temperature, the Core gravito-electric field is calculated; and the range of plasma sheath photo-electric fields is estimated. These outward DC fields are caused by the immense Solar energy flux pushing electrons outward. Significantly, the maximal displaced charge is set by a new "virial limit": the total (positive) electrical potential at r=0 is limited to the (negative) 10.keV gravitational potential at r=0. This gives a surface proton force of 8.6eV/Mm (3x gravity). This electrical energy is apparently released in pervasive, persistent "lightning jets", which are pinched proton beams penetrating the neutral Hydrogen atmosphere, broadly neutralized by co-propagating electrons. These energetic proton jets can glow as discrete filamentary Spicules near the surface, and are observed in reflected solar light as the diffuse K-Corona out to several Solar radii. This energetics sets the scale for electro-magnetic plasma dynamics, from the surface flares and electrical storms imaged by Solar Orbiter, to surface prominences, to persistent mass loss and intermittent CME events.

Theme(s): New Insights into Star Formation and Evolution, The Sun and Cool Stars in the Time Domain

23: Seeing Double: RVs Lagging Behind Magnetic Activity Indicators in HD 26965

J. Luhn (1); L. Zhao (2); J. Siegel (3); S. Halverson (4); C. Gilbertson (5); P. Robertson (1)
UC Irvine; Center for Computational Astrophysics, Flatiron Institute; Princeton; NASA Jet Propulsion Lab; Sandia National Laboratories

The many extreme precision, ultra-stabilized radial velocity (RV) spectrographs that have come online within the past few years now offer the ability to probe stellar signals with unprecedented fidelity. I will present recent high-cadence RV observations from NEID and EXPRES that have revealed strong rotationally modulated, magnetic-activity-induced RV signals in HD 26965, putting to rest planetary claims for this system. With the high precision and dense time sampling, we measure a time lag between the RVs and activity indicators. Standard activity mitigation techniques use Gaussian process modeling to simultaneously fit activity indicators (e.g., H-alpha) with their expected RV signal, assuming a simple spot model. While a time lag can be consistent with simple spot models—arising from the exact balance between the convective and rotational effects—I will show that a detailed model comparison suggests a more complex spot configuration or an astrophysical lag between activity and the associated RV signal. Under the best performing model, the H-alpha activity signal precedes the associated RV signal by nearly a week and a 2.2 m/s RV signal is reduced to 50 cm/s RMS. The unexpected behavior of the lagged GP model challenges the typical assumption that flux-based activity proxies and their RV effect will be in phase. Such a model will serve as a new guidepost for the ways in which magnetic activity may manifest in cool stars.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

24: The eROSITA All-Sky Survey - Stars in X-rays

J. Robrade
Hamburger Sternwarte

eROSITA (extended ROentgen Survey with an Imaging Telescope Array) is the soft X-ray instrument on the Spectrum-Roentgen-Gamma (SRG) spacecraft, that performs an all-sky survey in the 0.2-10.0 keV energy band. The eRASS data acquisition started in December 2019 and up to now four all-sky surveys with a duration of 0.5 yr each have been completed. The eRASS1 data that covers the first all-sky survey was released in January 2024 to the public. The accumulated eRASS:4 is about ten times more sensitive than the ROSAT All-Sky Survey and has an enhanced positional accuracy, spectral resolution as well as multiple temporal coverage, thereby providing new insights into a wide range of astrophysical phenomena. In total the eROSITA survey contains roughly six million X-ray sources, a fraction of about 10-20 percent of these are stars. The eRASS data enables detailed studies for many types of stellar sources, including a census of the solar vicinity, nearby young stellar populations and

star-forming regions. I present an overview of the stellar X-ray sky as seen by eROSITA, focussing on coronal emission from magnetically active, cool stars.

Theme(s): New Insights into Star Formation and Evolution, Cool Stars as Stellar Systems

25: Chemically Characterizing Massive Alpha-Element Enriched Red Clump Stars

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Stellar mergers are thought to be common in the Milky Way. A significant fraction of stars evolve in binary pairs and mergers are needed to help explain a range of phenomena, such as blue stragglers in star clusters. While stellar mergers are frequent, important events in the Galaxy there are limited ways to broadly identify post merger products. One possible way is to combine information on stellar mass with chemical composition. Massive alpha-enriched stars (MAES) are high mass (which suggests the star is young) and have 0.1 - 0.2 dex enhancements in their [\alpha/Fe], similar to older thick disk stars. Additional abundance measurements in MAES may provide clues on their formation history. Specifically, the ^{12}C/^{13}C ratio after the first dredge up and extra-mixing is strongly dependent on mass and may be a unique constraint on the masses of merged stars. To better understand the origins of MAES, we obtained high resolution optical spectra of multiple thin disk, thick disk, and MAES red clump stars using the Tull spectrograph on the McDonald 2.7m telescope and derived CNO abundances. We find most MAES in our sample have carbon isotope ratios similar to thick disk stars while a few stars have high ^{12}C/^{13}C, providing evidence that multiple formation channels may play a role in creating MAES.

Theme(s): Milky Way-scale Science and Big Data, Cool Stars as Stellar Systems

26: Flare energy–duration relations at different evolutionary stages

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It is generally believed that flares on late-type giant stars originate via similar physical processes and differ only by a scale factor in the energy levels from those observed on magnetically active dwarf stars. In this context, a generalized linear scaling for the logarithmic relation of flare energy and duration with a universal slope of \approx1/3 can be derived on a theoretical basis. We study this in more detail by looking for flaring giants (\log g \le 3.5) in the Kepler field. We created a database of \sim4000 flares from the 61 flaring Kepler giants found. Based on the data, a simple generalized scaling between flare energies and their corresponding durations

seems inappropriate because the logarithmic flare energy–duration relation is steeper for stars with lower surface gravity.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

27: X-Ray, UV, and Optical Observations of Proxima Centauri's Stellar Cycle

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Proxima Cen (GJ 551; dM5.5e) is one of only about a dozen fully convective stars known to have a stellar cycle, and the only one to have long-term X-ray monitoring. An earlier analysis found that X-ray and mid-UV observations, particularly two epochs of data from Swift, were consistent with the well sampled \sim7 yr optical cycle seen in ASAS data, but not convincing by themselves. The present work incorporates several years of new optical data from ASAS-SN and an additional five years of Swift XRT and UVOT observations, the latter now spanning 2009 to 2021. Analysis, which includes modeling and adjustments for stellar contamination in the optical and UV, reveals clear cyclic behavior in all three wavebands with a period that has lengthened, over the course of nearly a quarter century, from 7 yr to roughly 11 yr. We also show that UV and X-ray intensities are anti-correlated with optical brightness variations caused by rotational modulation, and provide updated evidence for our previous finding of a simple correlation between X-ray cycle amplitude and Rossby number over a wide range of stellar types and ages.

Theme(s): New Insights into Star Formation and Evolution, The Sun and Cool Stars in the Time Domain

28: Stellar Flares as a Case Study of Atmosphere Aided Studies of Transients in the LSST Era

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University of Delaware; University of Washington; Johns Hopkins University; Princeton University; Lawrence Berkeley National Laboratory

Due to their short timescale, stellar flares are a challenging target for the most modern synoptic sky surveys. The upcoming Vera C. Rubin Legacy Survey of Space and Time (LSST), a project designed to collect more data than any precursor survey, is unlikely to detect flares with more than one data point in its main survey. We developed a methodology to enable LSST studies of stellar flares, with a focus on flare temperature and temperature evolution, which remain poorly

constrained compared to flare morphology. By leveraging the sensitivity expected from the Rubin system, Differential Chromatic Refraction can be used to constrain flare temperature from a single-epoch detection, which will enable statistical studies of flare temperatures and constrain models of the physical processes behind flare emission using the unprecedentedly high volume of data produced by Rubin over the 10-year LSST. We model the refraction effect as a function of the atmospheric column density, photometric filter, and temperature of the flare, and show that flare temperatures at or above ~4,000K can be constrained by a single g-band observation at airmass X > 1.2, given the minimum specified requirement on single-visit relative astrometric accuracy of LSST. Having failed to measure flare DCR in LSST precursor surveys, we make recommendations on survey design and data products that enable these studies in LSST and other future surveys.

Theme(s): Milky Way-scale Science and Big Data

29: Revealing the Population of Volatile-Rich Planets Around Cool Stars

M. Greklek-McKeon (1); H. Knutson (1); S. Vissapragada (2); R. Hu (3); M. Saidel (1); J. Gomez Barrientos (1); G. Levine (4); G. Vasisht (3); A. Fukui (5); J. Korth (6); H. Parviainen (7); F. Pozuelos (8); K. Barkaoui (9); E, Pallé (7)
California Institute of Technology, Pasadena, USA; Harvard & Smithsonian Center for Astrophysics, Cambridge, USA; Jet Propulsion Laboratory, Pasadena, USA; Yale University, New Haven, USA; University of Tokyo, Tokyo, Japan; Lund University, Lund, Sweden; Instituto de Astrofísica de Canarias, Santa Cruz de Tenerife, Spain; Instituto de Astrofísica de Andalucía, Granada, Spain; Université de Liège, Liège, Belgium

Models predict that planets with water-rich compositions may be common around low-mass stars, but definitive evidence for the existence of water worlds has remained elusive. Recent JWST observations of sub-Neptune sized planets orbiting nearby M dwarfs found atmospheres enriched in CH_4, CO_2 and H_2O, but the mechanism for this enrichment is debated. To answer this question, it’s important to know if these two planets represent the broader population of sub-Neptunes, and to quantify the range of possible sub-Neptune atmosphere types. A first step to investigating this newly accessible subject is constraining the volatile atmospheric mass fractions of more small planets. This requires precise mass and radius measurements, but some of these systems are challenging targets for RVs. Dynamical interactions in near-resonant multi-planet systems produce transit timing variations (TTVs), and measurements of these TTVs constrain the planetary densities. Over the past three years, we have collected dozens of high SNR TTV observations using ground-based telescopes to characterize the planetary masses in multi-planet M dwarf systems, along with space-based XUV observations to measure the planetary radiation environments. Preliminary results from this survey have found several new small volatile-rich worlds, including some that are top candidates for atmospheric characterization with JWST and some of the coldest known volatile-rich rocky planets.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

30: Modelling stellar transition regions of F-G stars with advanced ionisation equilibrium

E. Deliporanidou, G. Del Zanna
University of Cambridge, UK

We employed advanced ionisation equilibrium models developed by Dufresne et al. (2024), which include charge transfer and density effects to study stellar irradiances in the EUV and UV for a sample of stars. Our sample includes \epsilon Eridani (K2 V), \alpha Centauri A (G2 V), Procyon (F5 V), and Proxima Centauri (M5.5 Ve). We remeasured the line fluxes from STIS datasets and used O IV as a density diagnostic to measure the formation pressure of ions in the transition region (TR). Our findings indicate significant improvements in modelling anomalous ions, such as Si IV, C IV and N V, from Li- and Na-like sequences, which produce the strongest lines in UV. We obtained first-time reliable estimates of some stellar chemical abundances in the TR, using a Differential Emission Measure (DEM) modelling. We also obtained significant improvements in the calculated-to-observed flux ratios. These results are compared with available photospheric abundances, demonstrating the effectiveness of our approach to look for evidence of the First Ionisation Potential (FIP) effect, in the TR of our stellar sample. Finally, we compared our results with an analysis of solar TR irradiances in the EUV.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

31: Blue wing asymmetries in Balmer lines during mid M dwarf flares and possible stellar mass ejections

Yuta Notsu (1,2); Adam F. Kowalski (1,2); Hiroyuki Maehara (3); Kosuke Namekata (4); Kenji Hamaguchi (5,6); Teruaki Enoto (7,8); Isaiah I. Tristan (1,2); Suzanne L. Hawley (9); James R. A. Davenport (9); Satoshi Honda (10); Kai Ikuta (11); Shun Inoue (7); Keiichi Namizaki (7); Daisaku Nogami (7); Kazunari Shibata (7,12)
University of Colorado Boulder, Boulder, USA; National Solar Observatory, Boulder, USA; NAOJ Okayama Branch Office, Asakuchi, Japan; NAOJ, Mitaka, Japan; NASA/GSFC, Greenbelt, USA; UMBC, Baltimore, USA; Kyoto University, Kyoto, Japan; RIKEN, Wako, Japan; University of Washington, Seattle, USA; University of Hyogo, Sayo, Japan; University of Tokyo, Meguro, Japan; Doshisha University, Kyotanabe, Japan

Flares are releases of magnetic energy in the solar/stellar atmosphere. During some M dwarf flares, chromospheric line profiles show blue wing asymmetries, which may provide clues for the early phases of stellar coronal mass ejections (CMEs), but this is still controversial. We conducted 31-nights of simultaneous optical spectroscopic and photometric observations of mid M dwarf flare stars, using APO 3.5m and SMARTS 1.5m telescopes. Among the 41 detected flares, 7 flares showed clear blue wing asymmetries in Balmer lines, with various correspondences in flare properties. The line-of-sight velocities of the blue-shifted components range from -73 to -122 km s^{-1}. Assuming that the blue-shifts were caused by prominence eruptions, the mass of upward moving plasma was estimated to be 10^{15} - 10^{19}g, which

are roughly on the relation between flare energy and erupting mass expected from solar CMEs. In contrast, the kinetic energies of these events are roughly two orders of magnitude smaller than the relation expected from solar CMEs, as also shown in previous M-dwarf CME studies. These low kinetic energies may be explained by assuming a difference in velocities between prominence eruptions and CMEs, though further investigation on the evolutions of these stellar chromospheric and coronal eruptions is needed. In this presentation, we introduce these results and discuss prospects for further multi-wavelength observations and collaborations with modeling studies.

Theme(s): The Sun and Cool Stars in the Time Domain

32: A Publicly Available Grid of Time-Dependent Stellar Flare Models

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University of Colorado, Boulder, USA; National Solar Observatory, Boulder, USA; Laboratory for Atmospheric and Space Physics, Boulder, USA; NASA Goddard Space Flight Center, Greenbelt, USA; University of Oslo, Oslo, Norway

We use the RADYN code to calculate a grid of 1D radiative-hydrodynamic stellar flare models that are driven by short pulses of electron-beam heating. The flare heating rates in the low atmosphere vary over many orders of magnitude in the grid, and we show that the models with high-energy electron beams compare well to the global trends in flux ratios from impulsive-phase optical stellar flare spectra. We also show comparisons to detailed spectral line shape properties in a large flare on YZ CMi. The self-consistent formation of the wings and nearby continuum level provide insight into how high-energy electron beam heating evolves from the impulsive to the gradual decay phase in white-light stellar flares. The grid is publicly available, and we discuss possible applications.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

33: From Radio to X-ray: Tracing YZ CMi's Flares Across the Spectrum

Vega, Laura D. (1,2,3); Villadsen, Jackie (4); Paudel, Rishi R. (1,3,5); Feliz, Dax L. (6); Youngblood, Allison (1); Barclay, Thomas (1); Quintana, Elisa (1); Schlieder, Joshua (1); Stassun, Keivan (7)
NASA Goddard Space Flight Center; University of Maryland, College Park; Center for Research and Exploration in Space Science & Technology (CRESST II); Bucknell University; University of Maryland, Baltimore County; American Museum of Natural History; Vanderbilt University

The active M dwarf star, YZ CMi, was simultaneously observed by the Very Large Array (VLA), TESS, and Swift in Jan. 2019. We focus on the radio data observed in 3 frequency bands: 2-4 GHz (S), 6-8 GHz (C), and 13-18 GHz (Ku), using a subarray of 8-10 antennas for each band,

over 4 ~5.5-hour epochs. Our study highlights the distinction between incoherent gyrosynchrotron flares and coherent bursts observed from YZ CMi. Incoherent gyrosynchrotron flares, primarily observed in the C and Ku bands, follow a classic flare profile and exhibit weak circular polarization, often correlating with simultaneous optical and X-ray flares. In contrast, coherent bursts, prominent in the S band, are characterized by highly polarized, bright low-frequency emissions that do not show a clear connection to optical or X-ray activity. The VLA's multi-frequency observations reveal that YZ CMi's gyrosynchrotron flares have a rising spectrum (optically thick) from 2 to 18 GHz, peaking above 15.5 GHz, a higher frequency than solar flares, due to stronger magnetic fields and higher coronal electron densities. Additionally, we present preliminary results comparing radio flares with simultaneous optical, X-ray, and UV counterparts. Our study delves into the characterization and temporal evolution of flares across various wavelengths, offering comprehensive insights into the dynamic processes in YZ CMi's atmosphere. Full results, including analyses of VLA, TESS, Swift, and NICER X-ray data, coming soon.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

34: 3D MHD Realistic Modeling of Subsurface Dynamics, Magnetic Fields, and Rotation of the Sun and Stars

Irina N. Kitiashvili
NASA Ames Research Center

Current advances in spectroscopic and spectropolarimetric observations allow us to retrieve information from the strength and distribution of magnetic fields. Because of the very limited spatial resolution of stars, it remains challenging to interpret the results and estimate errors and uncertainties of the magnetic field measurements. We take advantage of existing computational capabilities to model the dynamics of the Sun and stars in the presence of rotation and magnetic fields. In particular, we will discuss its properties of resulting meridional flows, differential rotation, and influence of dynamics and structure of the atmosphere on spectroscopic observations. In this presentation, we also cover a question of small-scale magnetic field generation and its impact on the observed properties of the photosphere.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

35: AU Mic Flares: A Multi-wavelength Study of a Magnetically Active Planet Host

E. Gilbert (1); T. Barclay (2); R. Paudel (2); L. Vega (2); J. Schlieder (2), et al.
NASA Jet Propulsion Laboratory / Exoplanet Exploration Program Office, Pasadena, USA; NASA Goddard Space Flight Center, Greenbelt, USA

AU Microscopii (AU Mic) is a young (20-25 Myr), nearby (9.8 parsec) pre-Main Sequence M1 dwarf star. AU Mic has a prominent debris disk, is host to several known exoplanets, and exhibits significant magnetic activity with both spot variability and frequent flaring events. These

traits make AU Mic an excellent target for understanding stellar magnetic processes and the impact of flares on planetary environments. We present a comprehensive analysis of AU Mic's flares using contemporaneous data from NASA's Transiting Exoplanet Survey Satellite (TESS) mission, the Neil Gehrels Swift Observatory (Swift), the Neutron star Interior Composition Explorer (NICER), and the Karl G. Jansky Very Large Array (VLA). Our multi-wavelength study aims to provide a comprehensive view of these flares, enabling a deeper understanding of the underlying magnetic processes and impact on its planets. Our findings will not only advance our understanding of stellar flares but also provide important context for assessing the habitability of planets around such active stars.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

36: The Surveying Ultrafast Rotators For SUperyoung Planets (SURFSUP) Precursor Survey

Te Han, Paul Robertson, the HPF team, the NEID team
University of California, Irvine

The high-cadence survey of TESS has revealed a new class of M-dwarf stars: the Ultra-Fast Rotators (UFRs) with stellar rotational periods under half a day. These young and magnetically active stars can produce surprisingly stable and long-lived spots (over hundreds of rotation periods), allowing modeling of the rotationally modulated photometric and spectroscopic variability. Their spot-modulated variability, despite being as high amplitude as other young stars, can thus be removed for possible radial velocity detection of rarely discovered young exoplanets. These exciting results require a precursor survey to select suitable UFRs for intensive RV measurements: inclined and non-binary UFRs for less broadened and single-lined spectra. The preliminary survey will be a catalog of characterization of this unique type of star. We are surveying ~70 targets found in TESS with Shane AO and NESSI for binarity check. Reconnaissance spectra are also taken with the Habitable-zone Planet Finder and NEID for stellar properties including effective temperature, stellar metallicity, and rotational velocity. We present the preliminary results of the SURFSUP precursor survey, in particular on a statistical binarity study.

Theme(s): New Insights into Star Formation and Evolution, The Sun and Cool Stars in the Time Domain

37: Double the Disks in DF Tau

Taylor Kutra (1); Lisa Prato(1); Benjamin Tofflemire(2); Rachel Akeson(3); Dominique Segura-Cox(2); Gail Schaefer(4)
Lowell Observatory, UT Austin, IPAC, Georgia State University

Young binary systems offer a unique opportunity to study the fragility of circumstellar disks in dynamically tumultuous environments. It is well established that the circumstellar disks in close binaries (i.e. separations of less than ~100 AU) are smaller, less massive and less abundant

than their more widely spaced or single counterparts. However, some systems surprisingly retain their disks. In this poster, I will present ALMA continuum and 12CO emission for one of these anomalous systems: DF Tau. This system is a close visual binary with a semi-major axis of only 14 AU; we find circumstellar disks around both the primary and secondary star. Other disk signatures, i.e. accretion measurements and H-band veiling, indicate only a disk around the primary star. We resolve this contradiction by proposing that the inner disk of DF Tau B is, at minimum, beyond ~0.06 AU.

Theme(s): Cool Stars as Stellar Systems

38: Coronal emission of old fast-rotating Sun-like stars

Nikoleta Ilić; Katja Poppenhaeger
Leibniz Institute for Astrophysics Potsdam

Recent years have seen great controversy about the rotational state of solar-mass stars older than the Sun: the stars expected to rotate slower than the Sun are nowhere to be found. These findings, accounting for potential observational biases, lead to the hypothesis that such stars may have a very weak or even non-existent magnetic dynamo rendering the stellar spin down through magnetic braking inefficient. Observations of the magnetic features of such stars might shed light on whether this is indeed the case. We will present preliminary results of the coronal X-ray emission capacity of old Sun-like stars with faster-than-expected rotation rates. These results will allow us to determine the state of the magnetic dynamo action of these 'old suns'. Additionally, as weak coronal emission, corresponding to weak magnetic dynamos, is potentially observable at very soft X-ray energies, we will present a method to discern astrophysical signals from spurious detector signals, which can be very pronounced at given energy ranges.

Theme(s): New Insights into Star Formation and Evolution, The Sun and Cool Stars in the Time Domain

39: Young close eclipsing binaries in the Orion Star Forming Complex

J. Hernández (1); S. Sanchez (1); F. Ahumada (2); D. Fernandez (2); M. Batista (3); G. Pinzón (3); R. Lopez (1); J. Serna (1) C. Roman (1); Alexandre Roman (2)
(1) Universidad Nacional Autónoma de México, Instituto de Astronomía, unidad académica Ensenada, México; (2) Universidad de la Serena, Chile; (3) Universidad Nacional de Colombia, Bogotá, Colombia

Binary stars and protoplanetary disks are natural byproducts of angular momentum conservation during stellar formation. Thus, detecting and characterizing young binary stars implies a more comprehensive understanding of the formation and early evolution of multiple stars and their impact on the formation of planetary systems. Through a general exploration of the TESS database for young star candidates in the Orion star-forming complex, we have identified a sample of seven young close eclipsing binaries (YCEB; separations< 0.1 AU)

exhibiting light curves where the secondary eclipse occurs approximately halfway between two primary eclipses. This characteristic is expected in binaries with very low eccentricity. Furthermore, the stellar rotation periods are similar to the orbital periods, suggesting that within a few million years, tidal effects in these systems have synchronized the orbit with the stellar rotation and have also led to a more circular orbit. Within our sample of nearby young eclipsing binary stars, one case stands out where the transit depth has substantially decreased over two years (between two TESS sectors), suggesting extreme erosion of the companion, possibly due to a super-flare detected in the light curve of the first TESS sector. In this work, we present the main features of the seven YCEBs.

Theme(s): Cool Stars as Stellar Systems

40: Estimating Radial Velocity Jitter from Photometric Variability in M Dwarfs

Rae Holcomb (1); Paul Robertson (1); Anjali Moore (1)
University of California Irvine, Irvine, CA

M dwarfs are prone to high levels of stellar activity, which remain a persistent barrier to radial velocity (RV) detection of low-mass planets. To take full advantage of the sub-m/s precision of next generation RV instruments, we need techniques to predict and mitigate the stellar “jitter” in RV time series. In solar-like stars, jitter correlates with short time-scale photometric variability, or “flicker”, hinting at an accessible method to diagnose RV activity levels in stars from their photometry alone. However, we cannot simply extend solar-based activity relationships to M dwarfs, since they are dominated by different sources of astrophysical activity. In this work, we study approximately 70 mid- to late-type M dwarfs observed by the Habitable-zone Planet Finder (HPF). We unite high-precision RVs observations with high-cadence photometry from TESS to search for the summary statistics of the photometric variability that best predict the RV jitter across the M dwarf sequence. We investigate how activity relationships change across the fully convective boundary, and assess how spot lifetimes influence the requirements for simultaneity of the photometric and RV data sets for correlating noise. Ultimately, we aim to identify the best techniques for predicting and characterizing RV jitter of M dwarfs from their photometry alone, which would give exoplanet scientists a powerful tool to efficiently design and execute high-precision RV surveys for Earth-sized planets.

Theme(s): The Sun and Cool Stars in the Time Domain

41: Simultaneous X-ray and optical variability of M dwarfs observed with eROSITA and TESS

Wilhelmina Maryann Joseph (1); Beate Stelzer (1); Enza Magaudda (1); Tobias Vičánek Martínez (2)
Institut für Astronomie & Astrophysik Tübingen (IAAT), Tübingen, Germany; Hamburg Sternwarte, Hamburg, Germany

M dwarfs are cool, highly active main sequence stars. To explore magnetic activity across stellar atmospheric layers, observations at various wavelengths are crucial. Variability, indicating activity, is best studied through multi-wavelength campaigns, but is challenging to conduct. Two all-sky surveys from the extended Roentgen Survey with an Imaging Telescope Array (eROSITA) in the soft X-ray band (0.2-10 keV) and the Transiting Exoplanet Survey Satellite (TESS) in the optical band provide a unique dataset of overlapping X-ray and optical observations. The ecliptic poles, where both surveys have the longest exposures, are ideal for variability studies. We focus on the southern ecliptic pole, where we identified 874 M dwarfs, of which the 25 X-ray brightest or variable stars simultaneously observed in both surveys were analyzed. Proximity (<100 pc), fast rotation (P_rot < 9 d), and high flare frequency characterize our sample. Optical and X-ray duty cycles correlate positively. Faster rotators are more variable in both wavebands. Frequently X-ray flaring stars show X-ray flares with optical counterparts more often. Using relations between optical and X-ray flares observed on the Sun, we estimate the energies of 21 X-ray flares following optical flares, despite eROSITA's low cadence. Optical and X-ray flare energies correlate. Two superflares have noticeably peculiar flare profiles. Our pilot study guides future research on a broader, diverse set of active stars.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

42: Model Choice Matters for Age Inference on the Red Giant Branch

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University of Florida, Gainesville, FL, USA

Galactic archaeology relies on accurate stellar parameters to reconstruct the galaxy's history, particularly through information on stellar ages. These ages are often derived from stellar models and isochrones, which are the most common tools used to infer the ages of large numbers of red giants. While observational errors were once the dominant source of uncertainty in age estimations, our research shows that the largest uncertainty now lies in the limitations of our theoretical models. In this poster, we assess the difference in age predictions of various widely used model grids for stars along the red giant branch. Using an open source software, we conduct a comparison of four different isochrone grids and we find that age estimations become less reliable if stellar mass is not known, with differences occasionally exceeding 80%. Additionally, we note significant disagreements in the models' age estimations as we move away from solar metallicity. Finally, we discuss a method for including theoretical uncertainties from stellar isochrones in age inferences of red giants, aimed at strengthening the precision of age-dependent methodologies across the galactic archaeology community.

Theme(s): New Insights into Star Formation and Evolution, Milky Way-scale Science and Big Data

43: Spectral Characterization of the Young Giant Planet AF Leporis b

Eric Nielsen (1); Robert De Rosa (2); Alexander Madurowicz (3); Zahed Wahhaj (2); Bruce Macintosh (4); Natasha Batalha (5); Sagnick Mukherjee (4); Theodora Karalidi (6); Caroline Morley (7); Jean-Baptiste Ruffio (8); Paul Kalas (9); Lea Hirsch (10); Anne Peck (1), William Roberson (1), Adam Smith (1), Jessica Klusmeyer (1), Hannah Gallamore (1)
New Mexico State University; European Southern Observatory; Stanford University; University of California, Santa Cruz; NASA Ames Research Center; University of Central Florida; University of Texas, Austin; University of California, San Diego; University of California, Berkeley; University of Toronto, Missisauga;

The exoplanet AF Lep b was detected by direct imaging follow-up of an accelerating young star in the beta Pictoris moving group. The combination of a precise astrometric mass and a well-constrained moving group age make this planet a key benchmark for understanding how the nature and evolution of giant planet atmospheres. We present new spectra of AF Lep b and a new analysis of its physical properties from its SED, as well as from its absolute and relative astrometry. Along with PZ Tel B, HR 7329 B, beta Pic b and c, and 51 Eri b, AF Lep b is part of an important isochronal sequence of substellar companions in the beta Pictoris moving group, spanning over an order of magnitude in mass.

Theme(s): Cool Stars as Stellar Systems, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

44: Understanding Accreting Brown Dwarfs Through Simulation Tools

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University of Massachusetts Amherst; Amherst College; Smith College

Many fundamental questions of brown dwarf formation remain unanswered. For example, what proportion of them form like stars and what proportion form like planets? To examine this question we observe accreting substellar objects, as their accretion rates are a useful probe of formation pathways and disk evolution. Stellar accretion rates tend to scale linearly with the mass of the star. This trend becomes less robust at substellar masses. However, the distribution also shows quite a bit of scatter, making quantitative analyses of trends more difficult. We present our work to improve a Monte Carlo simulation tool that models possible sources of observational uncertainty and physical effects (e.g. age, variability) that cause scatter. This simulation tool was previously demonstrated to be successful in replicating the observed stellar distribution, and we now extend this work to substellar masses. We present our efforts to compare simulation results to the Comprehensive Archive of Substellar and Planetary Accretion Rates catalog (CASPAR, Betti et. al 2023), a uniformly re-derived catalog of all observed accreting substellar objects. We hope to use the data from this catalog to delve further into the differences in substellar formation; such as model a separate population of objects that formed via disk fragmentation. Modeling scatter can grant us a thorough understanding of substellar accretion rates and can give us insight into their formation and accretion physics.

Theme(s): New Insights into Star Formation and Evolution, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

45: Stellar flares in hiding: Detecting stellar flares in photometric data using hidden Markov models

Arturo Esquivel (1); Yunyi Shen (1,2); Vianey Leos-Barajas (1); Gwendolyn Eadie (1,3); Joshua Speagle (3); Radu V Craiu (1); Amber Medina (4); James Davenport (5)
Department of Statistical Sciences, University of Toronto, Toronto, ON, Canada; Laboratory for Information and Decision Systems, Massachusetts Institute of Technology, Cambridge, MA, USA; David A. Dunlap Department of Astronomy and Astrophysics, University of Toronto, Toronto, ON, Canada; Department of Astronomy, University of Taxas-Austin, Austin, TX, USA; Department of Astronomy, University of Washington, Seattle, WA, USA

In this talk we will introduce our hidden Markov model (HMM) built for discovering stellar flares in a star's light curve data. HMMs provide a framework to model time series data that are non-stationary; they allow for different states at different times and consider a transition probability matrix that describes the probabilistic switching dynamics between states. In the context of stellar flares discovery, we exploit the HMM framework, allowing the light curve of a star to be in one of three states at any given time step: Quiet, Firing, or Decaying. This three-state HMM formulation by design enables straightforward identification of the entire duration of the flares, which is crucial for estimating the flare's energy, and is useful for studies of stellar flare energy distributions concerning both individual stars and population studies. We combine our HMM with a Celerite model that accounts for quasi-periodic stellar oscillations. Through an injection recovery experiment, we demonstrate and evaluate the ability of our method to detect and characterize flares in stellar time series. We also show that the proposed HMM flags more easily fainter and lower energy flares than traditional sigma-clipping methods. We will apply our method to multiple stars observed by the TESS mission and compare its performance with the one obtained from the sigma-clipping approach.

Theme(s): The Sun and Cool Stars in the Time Domain

46: The Lowell Observatory Solar Telescope (LOST) and the EXtreme PREcision Spectrograph (EXPRES)

J. Llama (1); J. Brewer (2); L. Zhao (3); A. Szymkowiak (4); D. Fischer (4)
Lowell Observatory; San Francisco State University; Flatiron Institute; Yale University

The signal induced by a temperate, terrestrial planet orbiting a Sun-like star is an order of magnitude smaller than the host stars' intrinsic variability. Understanding stellar activity is, therefore, a fundamental obstacle in confirming the smallest exoplanets. Here we present observations of the Sun with the Lowell Observatory Solar Telescope (LOST), a small telescope that acquires high-cadence, disk-integrated observations of the Sun continuously throughout the

day using the EXtreme PREcision Spectrograph (EXPRES). These observations will allow us to monitor the solar RV and correlate these data with disk-resolved images of the Sun. Using NASA's Solar Dynamics Observatory (SDO), we will examine concentrated regions of faculae that are known to drive RV variations on the Sun and whose RV impact remains little studied.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

47: M dwarf Age-Rotation-Activity Relationships: Results of the Living with a Red Dwarf Program

Scott G Engle, Edward F Guinan
Villanova University

Reliable ages are very difficult to determine for red dwarfs, due to their low masses and luminosities. Reliably determining the ages of red dwarfs has been a long-standing goal within stellar astrophysics, both due to the large number of red dwarfs that populate the local stellar neighborhood, and the increasing number of exoplanets that are discovered to orbit them. Twenty years ago, the Living with a Red Dwarf program was initiated with the goal of furnishing reliable age-rotation-activity relationships for M dwarfs. In this talk, we will present the recently published results of the program, along with continued efforts and results that have occurred since the publications, including the current status of the project's expansion into K dwarfs. We will also discuss some of the immensely invaluable works and data sets of the cool stars community, which were vital for the program, and an example or two of how we hope the program's results will in turn be of use to the scientific community.

Theme(s): The Sun and Cool Stars in the Time Domain

48: Starspots on Young Stars

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Accurate age and mass determinations for young pre-main sequence stars are by excess emission from large-scale starspots, accretion, and warm circumstellar disks that obscure the photosphere of the star. In an attempt to disentangle these phenomena, we present results from a near-infrared spectroscopic survey of 30 Weak-Lined and Classical T-Tauri Stars in Taurus-Auriga. Using BTSettl-CIFIST synthetic spectra we constructed composite models of spotted stars by combining a cool component representing the spots and a warm component representing the photosphere, along with continuum emission from a warm inner disk and accretion hot-spots. Using a Markov-Chain Monte-Carlo algorithm, we find the best-fit spot and photospheric temperatures, spot, disk, and accretion filling factors, as well as accretion temperatures. This allowed us to reproduce the 0.75-2.40 micron spectrum of these stars while disentangling the complicated multi-component emission. We then use our fit results to predict the veiling spectra for accreting stars before comparing these results to values from the

literature and new measurements from spectral line fitting. We find that starspots lead to large scatters in line-to-line veiling measurements while generating the need for a third emission component besides disk and accretion hotspot emission in order to reproduce the excess IYJ veiling spectrum.

Theme(s): New Insights into Star Formation and Evolution, Cool Stars as Stellar Systems

49: Identifying Young and Active Stars Among 1600 K Dwarfs within 40 pc with the CHIRON Spectrograph

Sebastián Carrazco-Gaxiola (1,2); Hodari-Sadiki Hubbard-James (2,3); Todd J. Henry (2); Tim Johns (1,2); Wei-Chun Jao (1); Leonardo Paredes (2,4); RECONS Team.
Georgia State University, Atlanta, GA, USA; RECONS, Chambersburg, PA, USA; Agnes Scott College, Decatur, GA, USA; University of Arizona, Tucson, AR, USA

K dwarfs account for 11% of all stars in the solar neighborhood. To put K dwarf activity in context with G dwarfs like our Sun, as well as M dwarfs that dominate the stellar population, we present the results of a chromospheric activity survey of nearby K dwarfs as part of the RKSTAR (RECONS K Stars) Survey. This work investigates the equivalent widths (EW) of three features found in K dwarf spectra: H alpha (6562.8 Å) and Ca II IRT (8542 Å) for activity, and Li I (6707.8 Å) for youth. The observed sample includes ~1300 of more than 1600 K dwarf primaries with declinations south of +30° within 40 parsecs observed with the CHIRON high-resolution echelle spectrograph (R=80,000) on the SMARTS 1.5m telescope at CTIO. We developed a standardized spectral analysis method that provides reliable equivalent width measurements and errors, as well as a new method to measure the EW of the Li I line accounting for the blend with the Fe I (6707.4 Å) line. We report a quiescent activity level for K dwarfs determined via Hα emissions along with the support of Ca II IRT core emission, to make final calls on active or inactive. Finally, we have discovered found ~10% of K dwarf stars near the Sun are young or active, which can be hosts of young exoplanets or harmful sites for orbiting worlds to have habitable environments. This effort has been supported by the NSF through grant AST-1910130, by NASA through grant 22-XRP22_2-0187, and via observations made possible by the SMARTS Consortium.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

50: The RKSTAR (RECONS K STAR) Catalog of 4447 Nearby K Dwarf Systems: First Results of Companions

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K dwarfs account for 11% of the stars in the solar neighborhood, making them the second most common star throughout the Universe. Exobiology studies indicate that they are less active and

likely host more ideal environments to produce and sustain life than their more active cousins, the M dwarfs. Our RKSTAR (RECONS K STAR) sample is the most extensive compendium of K dwarfs ever created, made possible with Gaia Data Release 3 (GDR3), as well as historical data for stars not in GDR3. With RKSTAR, we tackle the fundamental question: What do the stellar and planetary orbital architectures of companions to K dwarfs look like? RKSTAR will enable a wide range of scientific investigations, including everything from the mass contribution of K dwarfs to the Milky Way to identifying the best targets for future habitable exoplanet surveys. Here we present the RKSTAR census of 4447 K dwarf systems within 50 pc, with details about the primaries as well as statistics of companions found via GDR3, our speckle imaging and radial velocity surveys, and other supplemental data. We provide details to date for our radial velocity survey of a subset of 1081 K dwarfs within 40 pc and declinations -30 to +30, where we reveal Jovian-sized exoplanets, brown dwarfs, and hidden stellar companions with the use of the CHIRON spectrograph. This effort has been supported by the NSF through grant AST-1910130, by NASA through grant 22-XRP22_2-0187, and via observations made possible by the SMARTS Consortium.

Theme(s): Cool Stars as Stellar Systems, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

51: An Effect on Planetary Habitability over Galactic Time: The [Mg/Si] Ratio

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Many variables dictate whether a planet is habitable, and searching for habitable exoplanets is a complex and multifaceted topic. One such variable, and a critical feature that differentiates Earth from Venus or Mars, is the continued existence of significant plate tectonics. Mantle convection drives the movement of a planet's crust, continuously pushing new material to the surface. Studies of planets in our solar system show that plate tectonics are determined to some extent by planetary temperature and mass; however, a third crucial parameter is the composition of the planet's mantle. Geochemical modeling suggests that the [Mg/Si] ratio is essential for core-mantle boundary viscosity, allowing for a mantle's continuous convection and ongoing plate tectonics. Directly observing the parameters of exoplanets is still novel and mainly confined to their atmospheres, with the interiors of exoplanets prohibitively complex to determine. Still, studies suggest that the planetary ratios of [Fe/Si] and [Mg/Si] are very similar to their host stars, and one can infer them from the stellar host. These stellar abundances have changed as the Galaxy has evolved and enriched due to the evolving balance of supernova rates and yields. We use the abundances of stars with known ages to track the ratio of [Mg/Si] over time in the Milky Way, finding it to have decreased. This decrease may indicate that, at least along this one dimension, galactic habitability is decreasing over time.

Theme(s): Milky Way-scale Science and Big Data, The Sun and Cool Stars in the Time Domain

52: Resolved Disk Observations of Cool Mira Variables

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Mira variables are among the largest stars in the menagerie of cool stars. These 1-2 Msun stars exhibit dramatic year-long variations with delta_V > 3, the result of stellar pulsations that drive mass loss at 10-7 Msun/yr rates. We have been monitoring a select set of ~100 of these stars over the past two decades with optical interferometry, Spitzer, Sofia, and other facilities to provide unique insights into the dynamical physics and chemistry of these evolved stars. This mix of observations will combined into a Mira Reference Set, a laboratory to a wealth of different experiments on Miras.

Theme(s): New Insights into Star Formation and Evolution, The Sun and Cool Stars in the Time Domain

53: Mauve: a UV-Vis satellite dedicated to monitor stellar activity and variability

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Mauve is a satellite equipped with a 13-cm telescope and a UV-Visible spectrometer (with an operative wavelength range of 200-700 nm) conceived to measure the stellar magnetic activity and variability. The science program will be delivered via a multi-year collaborative survey program, with thousands of hours each year available for long baseline observations of hundreds of stars, unlocking a significant time domain astronomy opportunity. Mauve's mission lifetime is 3 years with the ambition of 5 years, and will cover a broad field of regard (–46.4 to 31.8 degrees in ICRS) during this period. This facility was conceived to support pilot studies and new ideas in science and is fully dedicated to time-domain astronomy. The main surveys to be executed by Mauve are long baseline observations of flare stars, Herbig Ae/Be stars, exoplanet hosts, as well as contact binary variables (RS CVn variables, symbiotic stars, Algol-type stars, etc.). Besides these major science themes, the spectrometer's data can be utilized to support and complement existing and upcoming facilities as a pathfinder, or conduct simultaneous/follow-up observations.

Theme(s): The Sun and Cool Stars in the Time Domain

54: Resolving Surface Features on Young M Dwarfs that Host Transient Corotating Material

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In the era of space-based, time-series photometry, 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 complex periodic variables (CPVs). These stars exhibit narrow dimming events with variable morphologies and depths that are periodic with the stellar rotation. With more systems now discovered with TESS, the growing sample is predominantly young (~<200 Myr), low-mass (M<0.4 M_\odot), and rapidly rotating (P<1 day). Without evidence for disk material, the most likely scenario is magnetically confined material orbiting in co-rotation with the star. To further investigate the source of this variability, we have monitored four CPVs in Upper Sco with moderate-cadence, high-resolution, near-infrared spectra from the IGRINS spectrograph (simultaneous H and K at R~45,000). We find large rotational velocities (vsini>150 km/s), consistent with near edge on orientations, and no significant radial-velocity variability. Reconstructed line profiles reveal evidence for large and evolving spot features, preferentially at polar latitudes. The results of our sparsely sampled data highlight CPVs as prime candidates for future Doppler tomographic studies to fully reconstruct the stellar surface, and to measure the orientation and size of the transiting material.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

55: Retrieving the Atmospheres of WISE 2150AB, a rare widely separated L+T binary system

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The WISE 2150-7520AB system is one of only three widely separated L+T brown dwarf binaries, with the secondary only recently discovered by the Backyard Worlds: Planet 9 citizen science program. By examining the atmospheres of the L1+T8 system in detail we can better understand their thermal profiles, chemical composition, and cloud properties that are tightly coupled with their formation and evolution. In this work, I use atmospheric retrievals to examine the atmospheres of WISE 2150AB. We test cloudless and cloudy models as well as a variety of chemical models. Here I present results from our atmospheric retrievals and compare them to retrievals of the widely separated L+T binary, SDSS J1416+1348AB.

Theme(s): Cool Stars as Stellar Systems, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

56: Space environment and interior heating of the Trappist-1 exoplanets during coronal mass ejections

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Trappist-1 is a remarkable star system that harbors 7 terrestrial exoplanets. The central flaring M-dwarf star may cause extreme space weather to which the planets are exposed. The effect of

flare-associated coronal mass ejections (CMEs) on the space environment of terrestrial exoplanets is an important aspect that can strongly influence their atmospheres, interior, their magnetospheres, if any, and ultimately the habitability of such planets. This system thus provides us a unique laboratory to study the impact of harsh space weather on terrestrial planets at different orbital distances. We perform magnetohydrodynamic simulations of the space environment of Trappist-1 b and e during the interaction with interplanetary CMEs. We model the interaction of density pulse and fluxrope CMEs with magnetized and non-magnetized planets. We aim to better understand the energy fluxes in the space environment of the planets driven by the interaction as a function of intrinsic magnetic field strength. We characterize magnetic variability at the surface of the planets during CME events which governs CME energy dissipation within the planetary bodies. We calculate interior ohmic heating and how planetary magnetic fields affect the energy dissipation. Ultimately, understanding the role of planetary magnetic fields in shielding the planets from external magnetic variations might have strong implications on our understanding of habitability on planets surrounding active M-dwarf stars.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

57: The Habitable-zone Planet Finder exoplanet survey: a close-in Neptune orbiting a very low-mass star

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The ultra-stable, near-infrared Habitable-zone Planet Finder (HPF) Doppler spectrometer is surveying nearby fully-convective M dwarfs for exoplanets. I will describe this survey, and introduce its first exoplanet discovery, LHS 3154b. LHS 3154 is a nearby (16pc) M6.5 dwarf hosting a Neptune-mass exoplanet on a close-in (a = 0.023 AU) orbit. The formation of such a massive planet on such a close-in orbit is difficult to reconcile with either the core accretion or gravitational instability models under typical assumptions for protoplanetary disks of very low-mass stars. With the HPF survey, we may constrain the occurrence rate of these Neptune-mass planets orbiting late-M dwarfs.

Theme(s): Cool Stars as Stellar Systems, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

58: Nature or nurture: constraining wide orbit substellar companions with JWST/NIRSpec retrievals

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Planetary-mass companions on wide orbits from their host star provide a window to look at their atmospheric composition with minimal stellar light contamination compared to closer in companions, with the extracted emission spectra supplying insights into understanding how planetary and substellar systems form and evolve. The origin of these companions remain unclear, as their low masses suggest formation mechanisms similar to that of giant planets, whereas their large orbital separation indicate for more stellar-like formation mechanisms. We present a NIRSpec/IFU G395H/F290LP spectrum of the planetary-mass companion 2MASS J22362452+4751425 b, a late L-type substellar object on a wide orbit of \sim260 AU from its K7 host star. The system is a likely member of the \sim120 Million year old AB Dor moving group, and is expected to have similar chemical composition as its fellow group members. The high signal-to noise and broad wavelength coverage by JWST bring forth new perception on molecular, thermal and cloud structures for the companion, which we constrain by applying atmospheric retrieval codes. Among our results, we retrieve an enhanced carbon-to-oxygen ratio (C/O) for the companion compared to what is expected from members of the same AB Dor moving group, which may place some constraints on how the history of the companion, whether it formed with similar nature as a brown dwarf, or was nurtured akin to a giant planet.

Theme(s): Cool Stars as Stellar Systems, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

59: Investigating the Faint Young Sun Paradox and the Solar Spin Down Problem

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The Faint Young Sun Paradox (FYSP) implies that liquid water on both Earth and Mars should have been frozen during the early evolution of the Sun, however, geological evidence suggests that both planets had liquid water during this period, presenting a paradox. The Sun's current mass loss rate is not large enough to yield a massive enough Sun at its Zero Age Main Sequence age to warm Earth's oceans, nor is it large enough to explain the Solar Spin Down Problem (SSDP). We utilize the one-dimensional MESA code to investigate the angular momentum and luminosity evolution of an initially more massive Sun with an initially larger mass loss rate for the first billion years of its existence to address both issues simultaneously. We also measure precise interferometric radii of intermediate mass stars within 60 parsecs using the CHARA Array. Measuring precise angular radii is important for characterizing the densities and atmospheres of exoplanets. We aim to address the FYSP and the SSDP through stellar astrophysics while applying observational measurements to understand the early Solar System and exoplanet habitability. If the results of investigating our hypothesis address either issue, they can change our understanding about how Sun-like stars evolve. If not, it implies that the rotational evolution of the Sun needs to be studied further, and the presence of liquid water may be more influenced by the atmospheric conditions on the planet itself.

Theme(s): New Insights into Star Formation and Evolution, The Sun and Cool Stars in the Time Domain

60: Simulations of faculae and spots on cool main sequence stars

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All stars with an outer convection zone are expected to have magnetic fields. Signature of these fields are found in the lightcurves in form of photospheric and chromospheric variability. However, the models that form the basis of interpretation of stellar light curves are usually either 1D (with phenomenological convection) or 3D but without magnetic fields. In order to understand the impact of magnetic fields on near surface convection and emergent intensity, we construct 3D rMHD near-surface models of magnetized regions like stellar faculae and starspots using the MURaM code. The faculae simulations range in field strengths from 100 to 500 G, and exhibit bright points, filigree and pores for the strongest field cases. The horizontally averaged structure shows a reduction in convective velocities, density and temperature stratification, compared to reference runs with only small-scale dynamo (SSD) field. We also showcase center-to-limb variation of synthetic spectra computed using the MPS-ATLAS code. The starspot simulations are initialized with a monolithic structure with 3 kG surface field and are run till a stable penumbra is formed, which is maintained with an enhanced horizontal field at the top boundary. We show preliminary plots of the azimuthally averaged thermal structure as well as field dependence of intensity features.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

61: Searching for Y Dwarf Binaries below the Diffraction Limit with JWST Kernel Phase Interferometry

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The James Webb Space Telescope (JWST) marks the beginning of a new era for brown dwarf and exoplanet direct imaging, opening the parameter space to Saturn-mass planets. However, coronagraphs on board JWST are restricted to separations beyond 400 mas. The Aperture Masking Interferometry mode of the NIRISS Instrument overcomes this limitation, transforming the telescope into an interferometer. This enables high-contrast imaging down to separations of 100 mas, but is limited to bright stars. For fainter objects, clear-pupil imaging can attain similar performance thanks to Kernel Phase Interferometry (KPI), a generalization of interferometric techniques to regular images. KPI, combined with the exquisite stability of JWST at 4.8 um, represents a unique opportunity to search for planetary-mass companions around the coolest and faintest brown dwarfs, of spectral type Y. We use the publicly available JWST-KPI pipeline

to analyze a survey of 20 Y dwarfs with JWST's Near Infrared Camera (NIRCam). This program recently unveiled the first Y+Y binary, WISE-0336, whose two components, separated by 1 AU, could both have planetary masses, depending on their age. Our KPI analysis probes mass ratios down to 0.1, thus entering the sub-Jupiter mass regime, at separations as short as 0.5 AU. Altogether, these results show how KPI can be leveraged for high-contrast imaging below the diffraction limit, paving the way for future companion searches around faint objects with JWST.

Theme(s): New Insights into Star Formation and Evolution, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

62: Time-varying X-ray emission from stellar flares and its impact on disk evolution

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X-ray and ultraviolet (XUV) radiation from pre-main-sequence stars is a key factor to control the gas evolution in protoplanetary disks through photoevaporation and ionization. Among the XUV sources in the system, stellar flares serve as a unique emitter of hard X-ray photons (> 10 keV) which drive various chemical reactions in the disk. While previous observation has reported that the time-variability in stellar X-ray luminosity has a non-negligible effect on disk ionization, theoretical work has still lacked precise modeling of X-ray flares, such as the nature of individual flares and hard X-ray emission. Given the necessity to incorporate the previously overlooked factors for elucidating the role of flares in disk evolution, we develop a model of time-varying X-ray emission in pre-main -sequence stars based on theories and observations of stellar flares. This model enables us to generate X-ray light curves of flares and their spectral energy distributions, including their temporal evolution. Using our X-ray model, we also conduct the radiative transfer calculation to investigate how X-ray flares affect the disk ionization. Our findings indicate that photons with > 10 keV play a critical role in disk ionization, underscoring the essential contribution of stellar flares to disk chemistry.

Theme(s): New Insights into Star Formation and Evolution, Cool Stars as Stellar Systems

63: Photometric and Astrometric Properties of Ultracool Subdwarfs

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Employing three new spectral models (LOWZ, ELF OWL, SAND), we computed photometric attributes to unveil undiscovered ultracool subdwarfs. We have calculated color-color diagrams

for identification of these objects. With the photometric performance of each color, we explored the chemical compositions and molecular signatures responsible for the differences in the atmosphere between metallicities. Furthermore, we explore the differences in metallicities within reduced proper motion space to explore tangential motion of these objects.

Theme(s): New Insights into Star Formation and Evolution, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

64: Searching for Pulsation in Low Mass Stars using Unsupervised Learning Techniques

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M-dwarfs, the most abundant stars in our solar neighborhood, are poorly understood due to discrepancies between theoretical models and observational data regarding their radius, and effective temperature. Asteroseismology offers a promising solution by studying stellar oscillations. Despite previous unsuccessful attempts to detect pulsations in M-dwarfs, TESS light curves provide a new opportunity due to their red sensitivity and low observing cadence. Our objective is to develop an unsupervised algorithm to classify M-dwarf light curves to identify pulsations. We have already trained an algorithm that uses Principal Component Analysis (PCA) and Uniform Manifold Approximation Projection (UMAP) for dimensionality reduction and K-Means for clustering on synthetic light curves. It was able to successfully classify light curves with different specific periods and randomized phase shifts. However, it produced poor classification accuracy when trained on light curves with randomized periods. As a potential solution, we are currently developing an auto-encoder, a neural network for dimensionality reduction. After training on synthetic data, we will apply our algorithm to TESS M-dwarf light curves to search for pulsations. Detecting pulsations in M-dwarfs is crucial as it would provide an independent method for reconciling differences between theoretical predictions and observational studies.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

65: The magnetic field on the eclipsing binary CU Cancri

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Measuring the magnetic field of stars can help us better understand the physical processes that govern its structure and evolution. We have performed a multi-scale investigation of the eclipsing binary CU Cnc in order to obtain both large- and small-scale magnetic field properties. This includes a magnetic field map obtained from spectropolarimetric observations and the unsigned magnetic field strength obtained from a time averaged intensity spectrum. The results

reveal large-scale field structures with typical strengths of about 100 G on both stars and significantly stronger small-scale fields of 3 to 3.6 kG. The small-scale field values are also in close agreement with previously predicted magnetic field strengths from magnetoconvective evolutionary models. This result indicates, that the magnetic field can significantly influence the structure and evolution of stars.

66: Chromospheric Mg I Emission Lines of Pre-Main-Sequence Stars

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To reveal the detail of the internal structure, the relationship between chromospheric activity and the Rossby number, N_{\rm R}(= rotational period P / convective turnover time \tau_{\rm c}), has been extensively examined for main-sequence stars. For active pre-main sequence (PMS) stars, the activity will be determined by using optically thin emission lines such as Mg I. To detect the Mg I chromospheric emission lines (\lambda 8807\ \mathrm{\AA}) from PMS stars, we analyzed high-resolution optical spectra of the 64\ PMS stars obtained with VLT/UVES and X-Shooter. We distinguish whether the Mg I emission lines were activated by dynamo activity or mass accretion from protoplanetary disks. The strengths of the Mg I emission lines of the PMS stars with no veiling are comparable to those of zero-age main-sequence (ZAMS) stars if both kinds of stars have similar Rossby numbers. The Mg I emission lines are considered to be formed by the dynamo activity similar to the ZAMS stars. The strengths of Mg I emission lines of the PMS stars with veiling are larger than those of the ZAMS stars. It suggests that the mass accretion from the protoplanetary disk makes a shock near the photosphere, and heats the chromosphere. The chromosphere of the PMS stars are activated not only by the dynamo process but also by mass accretion.

Theme(s): New Insights into Star Formation and Evolution, Cool Stars as Stellar Systems

67: Discovery of sixty new L subdwarfs with Gaia astrometry and population properties of L subdwarfs

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Ultracool subdwarfs are low-mass, low-luminosity objects with low metallicity. They have spectral types of late-type M, L, and T and metal classes of subdwarf (sd). extreme subdwarf

(esd), and ultra subdwarf (usd). Recently, we discovered more than 60 new L subdwarfs with Gaia astrometry and doubled the number of known L subdwarfs. To break the metallicity and Teff degeneracy in spectral classification of these 60 L subdwarfs, we studied both optical and NIR spectra. We present here this study, that help us to confirm the nature and constrain atmospheric parameters (Teff, [Fe/H], log g) of the L subdwarfs by optical-to-NIR spectral fitting to BT-Settl models (Allard et al. 2012). We also compare the observational properties of L subdwarfs (sdL, esdL and usdL) to those of L dwarfs.

Theme(s): Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

68: High-velocity blue-shifted Ha and Fe XXV Hea lines during superflares of the RS CVn-type stars

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Solar and stellar magnetic energy is released not only through radiation from flares but also through the motion of the plasma, Coronal Mass Ejections (CMEs). One particular observational advance over the past decade is the increase of measurements of blue wing asymmetries of Balmer lines, which may be attributed to prominence eruptions. However, whether these eruptions were developing into CMEs remained unknown because these observations lacked two things: detection of fast eruptions that exceed escape velocities and blue-shifted X-ray lines. RS CVn-type stars have the potential to become good targets for observing extreme (fast and massive) CMEs because large flares with its energy exceeding 10^{35} erg often occur on them. We conducted simultaneous optical spectroscopic and photometric observations of the RS CVn-type star V1355 Ori with Seimei and TESS in December 2020 and X-ray observations of the RS CVn-type star IM Peg with NICER in July 2023. As a result, we found a blueshifted excess component of Ha extending its velocity up to 760-1690 km/s during a superflare of V1355 Ori and a blueshift of the line center of the Fe XXV Hea line with its maximum Doppler velocity reaching 2200 \pm 600 km/s during a superflare of IM Peg. These high-velocity blueshifts, which overwhelmingly exceed the escape velocity of the stars, will clarify whether such events follow existing theories and scaling laws on solar flares and CMEs even when the energy scale far exceeds solar cases.

Theme(s): The Sun and Cool Stars in the Time Domain

69: A new approach in the kinematical study of the Orion complex in the Gaia era

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The young stellar cluster (YSCs) have become an important topic in recent years due to the data provided by astrometric and spectroscopic surveys. Their characterization allowed us to understand the star-forming history using both spatial and kinematic information. One of the most important reservoirs for the study of YSCs is the Orion star-sorming complex (OSFC) located in the solar neighborhood (<500 pc), which has an active process of star formation. In this work, we have selected a sample of kinematic pre-main-sequence candidates (ages < \sim30 Myr) with Gaia DR3 in the OSFC. After applying a hierarchical clustering algorithm in the 5D parameter space (sky position, proper motions, and parallax), we classified the recovered clusters under two regimes: Big Structures and Small Structures. In the first regime, we obtained 13 groups, with the majority forming an apparent filamentary structure. In the second regime, we found 14 minor groups, with 4 of them reported as new clusters. Furthermore, 12 other clusters were recovered as sub-structures from 5 larger groups, showing distinction in their kinematics and slight age differences. Additionally, by using radial velocity information, we analyzed the phase space in some regions of the OSFC, reporting two likely events of future close encounters between clusters. These results will be important for a posterior analysis using N-body simulations to evaluate statistically the future evolution of some regions of interest.

Theme(s): New Insights into Star Formation and Evolution, Milky Way-scale Science and Big Data

70: A fast NLTE Radiative Transfer Emulator Based on Neural Network for Stellar Activity

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Late type stars are known to manifest stellar activity such as spots and faculae. The facular contribution to the stellar spectra is still poorly understood, mainly because faculae are embedded within the stellar granulation, meaning their geometric shape must be considered when calculating their radiative properties. Current spectral modelling attempts focus on post-processing 3D magnetoconvection "box-in-a-star" simulations representing small facular patches. This necessitates calculating a large number of spectra (512 x 512 in this study). Since the facular contribution is particularly large in the UV, this work focuses on the UV spectra, where NLTE effect becomes important. NLTE calculations are also known to be computationally expensive, which limits the number of simulated spectra that can be calculated. Our work aims

to accelerate the NLTE radiative transfer calculations. By taking the stellar model atmospheres as the input and previously simulated spectra as the targeted output, we build the neural network model that emulates NLTE radiative transfer. Our first results for a G type star show 90% of the emulated spectra to be within 10% of the true spectra almost everywhere from 180nm to 300nm while the spectrum averaged over the box and the true mean spectrum agree within 1.5%. This allows us to construct accurate facular contrasts in a few seconds, which can also be applied to forward-modelling the transmission spectra.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

71: The Effects of Sunspot Moat Flows and Active Region Inflows on Stellar Radial Velocities

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While the radial velocity (RV) effects of magnetic spots and plages are relatively well studied, there are other, less well known stellar surface features that remain unexplored. Among these are sunspot moat flows (\sim 0.5 - 1 km s^{-1} flows outside spots, tangent to the surface, directed radially outward from spot center) and so-called ``active region inflows" (ARI). The latter are areas of quiet Sun surrounding plages, again with surface-tangent flows (\sim 10 - 50 m s^{-1}) but here predominantly directed radially inward towards plage center. We construct simple models of these regions and investigate how they, both individually and in aggregate, affect the observed solar RVs over time. We find that, despite their large areas (2 - 3 times that of their associated magnetic feature), symmetries in their flows reduce much of the net RV effect. The models suggest that moat flows and ARIs contribute at most a few cm s^{-1} to the RV jitter budget for the Sun. The large areas and slight net retrograde velocity in ARI make them the more significant of the two, and their effect will increase more rapidly with increasing activity. Moats and ARI thus can be important for detection and characterization of at least the smaller exoplanets.

Theme(s): New Insights into Star Formation and Evolution, The Sun and Cool Stars in the Time Domain

72: A Planet is Born: Leveraging the Keck Telescopes to Catch Planet Formation in the Act

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UC Irvine; University of Arizona; Caltech; Peking University; Universität Duisburg-Essen

Accretion processes in forming stars and exoplanets produce observable signatures in their spectral energy distributions in the form of UV continuum excess and emission lines. The relationship converting measured line fluxes to absolute accretion rates for T Tauri stars has

been determined empirically down to substellar masses, but a robust relationship calibrated for objects of planetary mass is yet to be determined. In this presentation, I will discuss preliminary results from a Keck pilot study to measure the accretion rates of planetary-mass objects using UV/optical and IR spectroscopy. The spectra of the planetary-mass objects in our sample are obtained near-simultaneously with both Keck-I/LRIS and Keck-II/NIRSPEC to ensure our L_{acc}--L_{line} relationships are robust to variability in accretion. I will also discuss the first detections of Pa\beta and Br\alpha in FU Tau A, a ~50 M_{Jup} brown dwarf host of a ~15 M_{Jup} planetary-mass companion, and their implications for accretion variability and brown dwarf formation scenarios in this benchmark system. Our Keck campaign will calibrate and extend empirical relationships between hydrogen recombination line fluxes and accretion luminosity down to planetary masses. These observations will place the first UV-calibrated constraints on Br\alpha emission in accreting substellar objects, and I will conclude my presentation with discussion of the outlook for using infrared hydrogen emission lines as a protoplanet search strategy in the era of JWST.

Theme(s): Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

73: Monitoring Magnetically-Sensitive Spectral Features (Balmer Lines) Variability in M Dwarfs

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M Dwarfs, predominant among stars, offer a promising path for discovering Earth-size exoplanets due to their smaller sizes. Yet, their intense magnetic activity poses challenges for exoplanet detection and characterization, with active regions mimicking planetary signals in radial velocity and transmission spectroscopy. Understanding M dwarf magnetic activity, from internal dynamos to surface starspots, is vital for advancing exoplanet research. We monitored H\alpha, H\beta, and H\gamma emission lines in 14 M Dwarfs to study short-term variability and emission sources. The sample ranged from M1 to M8.5 spectral types, encompassing various evolutionary states, including young stars, T Tauri stars, and main sequence stars, as well as binaries and single stars. Spectra were obtained using the MDM Observatory's Ohio State Multi-Object Spectrograph on the 2.4m Hiltner Telescope, combined with TESS photometry to investigate evolving spot morphology and rotation periods. Sporadic short-term variability (equivalent width differences \gtrsim -1) in Balmer lines was observed in some stars, occurring on timescales (\gtrsim 15 min) much shorter than stellar rotation periods. In this poster, we quantify the type of variability we are seeing but also how its similar or different between each Balmer line. We also re-examine the amplitude-activity relation.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

74: Spatial Resolution Affects Solar Open Magnetic Flux Estimate

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The solar open magnetic flux inferred from spectropolarimetric observations lacks definite calibration. Existing estimates are well below the in situ counterparts, and can vary significantly from one observatory to another. Here we assess the effect of spatial resolution on the flux estimate using synthetic data from an MHD simulation. We show that the mean magnetic flux density is underestimated when the magnetic structures are unresolved, due to the intrinsic nonlinearities in the inference process. We further demonstrate that the inclusion of a "filling factor" parameter improves the estimate, but is unable to recover the ground truth due to parameter degeneracies. These effects unfortunately limit the accuracy of the open magnetic flux estimate with conventional methods.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

75: Stellar characterisation through 3 observational techniques

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The study of stellar magnetic activity on different time scales is important because it provides insight into the physical mechanism behind the interaction between convection and the rotation of stars. On the one hand, the study of long-term activity through different spectral lines has been possible using spectroscopic data obtained from ground-based observations. On the other hand, satellite photometric observations (e.g. Kepler and TESS) permit us to deepen the field of short-term studies by obtaining stellar rotation periods and flare frequencies with higher precision. In addition, interferometric data allow us to study these objects in more detail and to characterise them by obtaining angular diameters, limb darkening, etc., which are essential parameters for the analysis of stellar and planetary characterisation. The combination of the three observational techniques mentioned above allows us to make progress in the understanding of the physical phenomena that govern the interior and exterior of stars, achieving a better understanding from the stellar dynamo to the planets that orbit around dwarf stars. In this work we present the study of some FGKM dwarf stars by spectroscopic and photometric observations as well as some preliminary results obtained using the Stellar Parameters and Images with a Cophased Array (SPICA) interferometer installed at the Center for High Angular Resolution Astronomy (CHARA) at the Mount Wilson Observatory.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

76: Determination of the Initial Mass Function of Nearby Young Moving Groups

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The solar neighborhood is populated with Nearby (< 200 pc) Young (< 100 Myr) stellar co-Moving Groups (NYMG; e.g. Torres et al., 2006; Gagné et al., 2018; Kerr et al., 2021). Although their origin is a matter of debate, their ages could be one order of magnitude smaller than their dynamical times around the Galaxy which supports the idea of these groups being remnants of stellar populations scattering in the galactic disc. The NYMGs are ideal candidates for the observational study of the Initial Mass Function (IMF) because of their proximity and low extinction, and because their youth guarantees that only their most massive stars have evolved out of the main sequence. Then, their mass distribution equals the IMF in most of the stellar and sub-stellar mass ranges. In this poster, We will present a robust determination of the IMF of 5 NYMGs in the mass range 0.04 \leq M/M_\odot \leq 5. The members of these groups were identified using the Gaia DR3 catalogue (Gaia Collaboration et al., 2022) and a computational tool that applies a clustering algorithm in the phase-space based on DBSCAN (Ester et al., 1996), makes a photometric selection, and computes robust estimations of the completeness and expected contamination of each sample.

Theme(s): New Insights into Star Formation and Evolution, Milky Way-scale Science and Big Data

77: Circularly polarized modulated radio emission from a low-mass dipper star system: 2M0508-21

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2M0508-21 is a young (<25 Myr old) M-dwarf binary system with a 6.7- hours photometrically observed period. It is known to exhibit IR excess emission, along with NUV and X-ray excess emissions and flares, in addition to a 10% dip seen in optical light curves. We observed this unique system at radio frequencies with the uGMRT band 4 (550-950MHz), covering twice 90% of the rotation period in two observations scheduled a month apart in 2023. We detected emission in both Stokes I and Stokes V with an S/N ~ 25. The emission showed significant circular polarization ((about 30-40%), suggestive of being plasma emission or electron cyclotron maser emission, and carrying information about the magnetic fields present in the system. It also displayed peculiar variability in the circularly polarized signal when phase-folded. I will present our results of the radio observations in detail, along with shedding some light on the possible interpretations of the observed circularly polarized signal and its behavior in the context of the magnetic activity of the stars.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

78: Can Planets Form Around Evolved Stars? - A Case Study of AC Her

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It is now firmly established that planet formation occurs within the protoplanetary disks surrounding young stellar objects. Remarkably, similar disks have been identified around a specific category of evolved stars—post-Asymptotic Giant Branch (post-AGB) binaries. These disks are believed to originate from the intense interaction within the inner binary system during the AGB common envelope phase. ALMA observations indicate the stability of these disks with Keplerian motion. SED observations reveal about 10% of these disks exhibit inner disk cavities with size surpassing the theoretical dust sublimation radius, similar to transition disks identified around young stars, possibly linked to the process of planet formation. Our current investigation involves imaging these post-AGB binary objects using the CHARA Array, with the primary goal of uncovering insights into second-generation planet formation. We are focusing on a target sample comprising 10 potential transition disks. Our preliminary observations show that in AC Herculis, both the binary disk truncation radius and the dust sublimation radius are smaller than the observed disk cavity radius. We suggest that the additional disk cavity in AC Her could have been created by a massive planetary companion.

Theme(s): The Sun and Cool Stars in the Time Domain

79: Demographics of Giant Exoplanets from a Combination of Direct Imaging and Radial Velocity Surveys

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Combining direct imaging and radial velocity techniques is a powerful approach to measuring the demographics of giant exoplanets from 0.01 au to 1000 au. These two techniques are highly complementary with radial velocity being most sensitive to planets close to their host stars, while direct imaging is most sensitive to giant planets at larger orbital separations. We combine survey results from direct imaging (the Gemini Planet Imager Exoplanet Survey) and radial velocity (the California Legacy Survey) to more extensively probe the occurrence rates of giant planets across a wide range of semi-major axes. We fit a joint demographic population to the combined dataset and present early results from our analysis. Our findings echo previous work with a peak in giant planet occurrence rate near the snow line, consistent with predictions of pebble accretion. Additionally, we investigate the relationship between giant planet occurrence rates and stellar host mass.

Theme(s): Cool Stars as Stellar Systems, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

80: Correcting Exoplanet Transmission Spectra for Stellar Activity with an Optimised Retrieval Framework

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Chromatic contamination arising from photospheric heterogeneities e.g. spots and faculae on the host star is a significant noise source for exoplanet transmission spectra. If not corrected for, this contamination introduces substantial bias in our retrieved planetary parameters. We use two stellar models of differing complexity, namely differing in the treatment of the limb darkening effect, to explore the biases introduced by starspot contamination in retrieval under varying degrees of stellar activity. Using the retrieval framework TauREx3 and a grid of 27 synthetic, spot-contaminated transmission spectra we investigate the presence of any model-dependent biases and determine what level of model complexity is required in order to accurately extract the planetary parameters. We confirm that including stellar activity parameters within the retrieval minimises bias under all activity regimes considered, with the simpler model performing best under low-to-moderate activity conditions. For the highest activity cases, some minor residual bias remains due to the retrieval model neglecting the interplay between the spot and the limb darkening effect. As a result of this, we find larger errors in retrieved planetary parameters for central spots (0 degrees) and those found close to the limb (60 degrees) than those at intermediate latitudes (30 degrees). Finally, we extend our retrieval analysis to multiple spot configurations and separations into umbra and penumbra.

Theme(s): Cool Stars as Stellar Systems

81: Completing the census of wide ultracool companions among Gaia high proper motion stars

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Aiming to complete the inventory of very low-mass stars and sub-stellar objects in binary and multiple systems detected by Gaia, we mined the DR3 catalog to identify such candidates among Gaia high proper motion (μ >=100 mas/yr) sources. Using Gaia astrometry we searched for common proper motion objects, located at consistent distances and with up to 10,000 AU projected separations. An internal cross-match of DR3 sources with μ >= 100 mas/yr and parallax > 3 x error, requiring proper motions (μα cosδ, μδ) consistent within 50 mas/yr, parallaxes overlapping within 10-sigma errors and angular separations corresponding to up to 10,000 AU returned 23,537 binary stars, 578 triples and 18 quadruples. Within these, we selected components with M_G>16 mag and G-RP color indicative of an M7 and later spectral type and identified 124 candidate binaries and 7 triples. We estimate that the faintest ones (having M_G~18 mag) are of the early to mid-L types. Here we show the characteristics of the input sample of high proper motion objects, present early findings on the selected ultracool dwarf companion candidates and outline the plans for their further studies. The majority of our pairs and multiples are located within 100 pc of the Sun. The confirmation and spectroscopic characterization of previously overlooked UCDs forming part of these systems constitute a small but necessary step towards getting full completeness of stellar and sub-stellar inventory within our 100 pc neighborhood.

Theme(s): Milky Way-scale Science and Big Data, Cool Stars as Stellar Systems

82: The Multiple Facets of Silicon Dioxide Clouds in Sub-Stellar Atmospheres

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Silicate clouds in sub-stellar atmospheres have been suspected since Spitzer observations of brown dwarfs. With the now operational MIRI instrument on JWST, we can more deeply probe silicate features from 8 to 10 \mum, exploring specific composition, particle size, and particle structure. Recent characterization efforts have led to the identification in particular of silicon dioxide (SiO_2) cloud features in both brown dwarfs and transiting giant exoplanets. Previous modeling has primarily focused on crystalline quartz or amorphous silica to match observations. Here, we explore the possibility of other silica polymorphs that may be more likely to form at the pressure and temperature conditions of substellar upper atmospheres. We show how these polymorphs may be observationally distinguished from each other with current JWST observations. We also explore how such particles could be dynamically lofted and sedimented throughout the atmosphere, and what this may mean for the underlying chemical and dynamical processes governing these objects.

Theme(s): Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

83: Strong Resemblance between Surface and Deep Zonal Winds inside Jupiter Revealed by Juno Measurements

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Jupiter’s atmosphere interior is a coupled fluid dynamical system strongly influenced by the rapid background rotation. While the visible atmosphere features east–west zonal winds on the order of ~100 m/s, zonal flows in the dynamo region are significantly slower, on the order of ~cm/s or less, according to the latest magnetic secular variation analysis. The vertical profile of the zonal flows and the underlying mechanism remain elusive. The latest Juno radio tracking measurements afforded the derivation of Jupiter’s gravity field to spherical harmonic degree 40. Here, we use the latest gravity solution to reconstruct Jupiter’s deep zonal winds without a priori assumptions about their latitudinal profile. The pattern of our reconstructed deep zonal winds strongly resemble that of the surface wind within ±35° latitude from the equator, in particular the northern off-equatorial jet (NOEJ) and the southern off-equatorial jet. The reconstruction features larger uncertainties in the southern hemisphere due to the north–south asymmetric nature of Juno's trajectory. The amplitude of the reconstructed deep NOEJ matches that of the surface wind when the wind is truncated at a depth ~2500 km, and becomes twice that of the surface wind if the truncation depth is reduced to ~1500 km. Our analysis supports the physical picture in which a prominent part of the surface zonal winds extends into Jupiter’s interior significantly deeper than the water cloud layer.

Theme(s): Cool Stars as Stellar Systems, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

84: The observational picture of silicate clouds in brown dwarf atmospheres and further JWST prospects

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Silicates are the only spectroscopically detected condensates in substellar atmospheres so far. Silicate dust accounts for the increasingly red spectra of L-type dwarfs. However, dust clouds also pose a conundrum around the L-to-T spectral type transition, wherein their presumed sedimentation from the atmosphere occurs over an unexpectedly narrow 1200-1300 K range. Observationally, late-L and early-T dwarfs span a wide range of colors and spectral morphology, which atmospheric models struggle to self-consistently fit into a cooling sequence. The

conundrum is now being resolved through direct spectroscopy of the 8-11 micron silicate absorption signature of dust clouds in L dwarfs. Spitzer spectra show silicates in most L1 to L8 (2200 K to 1300 K) dwarfs, peaking in strength at mid-L types. Intriguingly, silicate absorption is seen to correlate with the spin axis inclination of L3–L7 dwarfs. Mid-L dwarfs viewed at near-equatorial latitudes display stronger silicate absorption than mid-L dwarfs viewed closer to pole-on. This further correlates with redness and presence of photometric variability in L dwarfs, and reveals a novel result: equatorial latitudes are cloudier and redder than the poles. That is, the observed properties of L dwarfs depend on their viewing geometry. On-going spectroscopy with JWST will probe the effect of substellar age in this picture, as archival Spitzer evidence already points to a further dependence of dust mineralogy on surface gravity.

Theme(s): Cool Stars as Stellar Systems, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

85: Probing the Formation Mechanisms of Brown Dwarfs and Planetary-Mass Objects using Keck/LRIS

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Measuring accurate accretion rates of stellar and substellar objects will allow us to probe their fundamental formation pathways. Previous studies of excess continuum and line emission have enabled comparisons of accreting objects' spectra across mass regimes, ranging from T Tauri stars to substellar objects. However, the differences in accretion between these objects remains unclear. We present a two-year study using the Keck Low Resolution Imaging Spectrometer (LRIS), which has broad spectral coverage spanning 3200-10000 Å. In particular, we targethoned in on a sample of six substellar objects ranging in spectral type from M5.5-M9.25 and with masses ~8-60 MJup. Our sample expands the number of substellar objects with resolved UV excess measurements substantially. Prior to our study, only four substellar objects had both spectroscopic continuum and line excess measurements, and our sample doubles this population. Our larger sample will allow us to probe the physical mechanisms producing accretion emission in substellar objects. Comprehensive characterization of accretion derived from both continuum excess and line emission is necessary to calibrate line-to-total accretion luminosity scaling relations and improve both accretion models and estimates of accretion rates. The spectral analyses from this study will aid interpretation of future protoplanet detections, as well as general understanding of the accretion physics of young protoplanets.

Theme(s): New Insights into Star Formation and Evolution, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

86: HD 206893b at High-Resolution with KPIC

Ben Sappey

87: Can Photometric Flares Detected by Ground and Space Based Telescopes Be Used To Identify Activity Cycles in M-dwarf stars?

Dax Feliz

88: Discovering planetary-mass Brown Dwarf candidates in the Small Magellanic Cloud

Elena Manjavacas

89: The Environoment of Faculae- vs. Spot-Dominated Stars

Eliana M. Amazo-Gómez

90: Provisional NASA ExEP Mission Target Star List for the Habitable Worlds Observatory

Eric Mamajek

91: Star Formation in Clusters: Orion Nebula Cluster and Westerlund 1

Lingfeng Wei

92: X-rays in the Prime of Life: The Turbulence of Wolf 359

Scott Wolk

Digital Posters

The Search for Mode Coupling in the Lower Solar Atmosphere

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We have analyzed oscillations in magnetic bright points to study wave propagation between the photosphere and chromosphere to establish the types of waves present and to search for possible wave heating mechanisms. Our data were obtained from observations in July 2011 with the Rapid Oscillations of the Solar Atmosphere (ROSA) instrument at the Dunn Solar Telescope. Observations were made in wave bands of G-band and H\alpha with good seeing. Speckle reconstruction and several post facto techniques were applied to return science-ready images. The spatial sampling of the images was 0.069 arcsecs/pixel (50 km/pixel). Wavelet and Fourier analyses were used to identify traveling MHD waves and derive frequencies in the different bandpasses. We have found oscillations in the G-band MBP with frequencies between 1.5 to 3.5 mHz. Corresponding MBP in the lower solar chromosphere observed in H\alpha showed a frequency range of 1.5 to 4.2 mHz. In about 40\% of the MBPs, the ratio of H\alpha to G-band frequencies was near 2. Thus, these oscillations show a form of mode coupling, where the longitudinal waves in the photosphere are converted into a transverse waves in the chromosphere. Although the energy flowing through MBP may not provide the necessary energy to heat the chromosphere and corona, they will help us understand the types of MHD waves in the lower solar atmosphere and overall energy budget.

Theme(s): The Sun and Cool Stars in the Time Domain

Chromospheric Activity and Its Relation to Rotation in Cool Dwarf Members of Coma Berenices

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Spectroscopic observations of low-mass stars in open clusters are critical to understanding the dependence of magnetic activity on stellar properties and their evolution. Coma Berenices, one of the nearest, yet understudied, open clusters—similar in age to the more famous Praesepe and Hyades clusters (600-800 Myr old), is among the best available laboratories for examining the dependence of magnetic activity on rotation for stars with masses <1 M_\odot. We present a

study of the rotation-chromospheric activity relation in this cluster. We collected mid-resolution optical spectra for its members, which we used to measure the H\alpha equivalent width (EW) and to estimate H\alpha luminosity (L_\mathrm{H\alpha}) for stars with H\alpha emission. We used TESS and ZTF light curves to measure rotation periods to complement the existing periods in the literature. We find that almost all M dwarfs exhibit H\alpha emission, with binaries having the same overall color-H\alpha EW distribution as single stars. This distribution is almost identical to that of Praesepe's members. In the Rossby–L_\mathrm{H\alpha}/L_\mathrm{bol} plane, unsaturated single stars follow a power-law with index \beta = -2.0\pm0.5 for Rossby > 0.2. These results provide essential insight into the relative efficiency of magnetic heating of the stars' atmospheres, thereby informing the development of robust age-rotation-activity relations.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

What do observations of proto-brown dwarfs tell us about their formation mechanism?

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There is still a vigorous debate about which is the dominant formation mechanism of brown dwarfs (BDs). For this, it is crucial to study proto-BDs, i.e., BDs in their earliest evolutionary stages. In this poster, the recent efforts aimed at searching, identifying and characterising proto-BD candidates in nearby star-forming regions are presented, and revised requirements for an object to be a promising proto-BD candidate are provided, based on a new correlation between the internal luminosity and the accreted mass. By applying these requirements to our compilation of proto-BDs from the literature, a list of 67 promising candidates was compiled. Updated correlations of infall/outflow properties with bolometric luminosity are provided down to the low-mass BD regime, where no significant deviations are apparent. Furthermore, the number of proto-BD candidates in different clouds seem to correlate with cloud properties. What is more, the proto(star-to-BD) ratios for the different clouds unveil a particular underproduction of low-mass proto-BD candidates in Ophiuchus compared to Lupus and Taurus. Possible explanations for this behavior are discussed, including heating of the Ophiuchus cloud by the nearby OB stars. The overall results of this work, along with the possibility that the planetary-mass regime of the IMF is subtly shaped by stellar feedback, tend to favor a Jeans-fragmentation process, and therefore a star-like formation scenario down to the planetary boundary.

Theme(s): New Insights into Star Formation and Evolution, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

Assessing the completeness of the updated CNS5 catalogue

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The stellar and sub-stellar content of the solar neighbourhood serves as a benchmark for testing stellar evolution models, for selecting targets for exoplanet surveys, and can improve our understanding of the overall Galactic demographics. To mitigate observational biases, it is essential to characterise the completeness of the sample under consideration. The Fifth Catalogue of Nearby Stars (CNS5) provides the most volume-complete sample of all known stars and brown dwarfs within 25 pc of the Sun. The CNS5 is compiled based on trigonometric parallaxes from Gaia DR3 and Hipparcos, and supplemented with astrometric data from Spitzer and ground-based surveys carried out in the infrared and radio wavelengths. Since its original release, the CNS5 has been continuously updated with observational data for nearby stars from various sources. In this talk, we review this census, including new additions to the 25 pc sample, and present an update of the CNS5. To assess the completeness of the catalogue, a Kolmogorov-Smirnov test is used to compare the observed spatial distribution of objects with a uniform space density model. We evaluate the completeness of the CNS5 for different types of objects and as a function of position in the sky. We also discuss how a well-characterised, volume-complete sample of nearby stars can help to constrain empirically the Gaia DR3 selection function and reveal its peculiarities at intermediate magnitudes.

Theme(s): Milky Way-scale Science and Big Data, Cool Stars as Stellar Systems

ROME: THE 5 GHZ ARECIBO SEARCH FOR STAR-PLANET INTERACTIONS

Alex Wolszczan/Matthew Route

Studying the Variability of M Dwarfs from Hours to Months to Decades with the CTIO 0.9m and TESS

Aman Kar (1,2); Todd J. Henry (2); Andrew A. Couperus (1,2); Madison LeBlanc (1,2); Eliot Halley Vrijmoet (3,2); Wei-Chun Jao (1)
Georgia State University; RECONS Institute; Smith College

M dwarfs account for 3 out of every 4 stars in the Solar Neighborhood and presumably offer enduring and stable environments for planetary systems. In our project, ATLAS (A Trail to Life Around Stars), we are compiling a variability catalog of M dwarfs within 25 pc to identify the most and least variable stars in a volume-complete sample. Here we present our assessment of stellar variability at different timescales: short-term (minutes to hours; due to flares), mid-term (days to months; due to stellar rotation), and long-term (years to decades; due to stellar cycles). We have identified 1750 M dwarf systems in the southern sky within 25 pc via Gaia DR3 parallaxes. These long-term results are based on the 24-year RECONS effort at the SMARTS 0.9m at CTIO. We present long-term variability results on ~400 M dwarfs and highlight in detail

32 M dwarfs with confirmed exoplanets. Of these, 6 vary < 2%, 25 vary between 2-6%, and only 1, Proxima Centauri, varies by > 6%. We augment these results with mid- and short-term results from TESS (~90% coverage of our sample). TESS observed 23 out of 32 ATLAS exoplanet hosts and found 17 varying by <1% and 5 showing flares. Overall, it is clear that some M dwarfs are more photometrically stable than others across all timescales, suggesting that specific stars warrant further attention in the search for habitable worlds. This effort has been supported by the NSF through grant AST-2108373 and via observations made possible by the SMARTS Consortium

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

Lithium's Labyrinth in low-mass red giants: A Mystery Explored

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7Li is a key tracer of stellar structure and mixing processes. While models predict lithium depletion in low-mass giants, a small subset exhibits unexpectedly high lithium, posing a challenge in astrophysics. Various hypotheses have been proposed to elucidate this phenomenon, including engulfment of substellar objects, in situ production via Cameron–Fowler mechanism, enhanced mixing induced by tidal interactions with binary companions, and mixing triggered by core helium-flash in low-mass stars. To address this, we integrated spectroscopic (HET-HPF, GALAH and LAMOST surveys), photometric (2MASS and WISE), and asteroseismic data (Kepler and TESS missions). We discern potential mechanisms for Li enhancement, including in situ He-flash and He-flash triggered by external events like mergers. Our investigation reveals significant correlation between Lithium content and stellar mass, with primary red clump giants showing pronounced Li enhancement compared to secondary red clump giants. We have also scrutinized near-infrared spectra to probe the relationship between photospheric Li abundance and chromospheric He I λ 10830 absorption, as the He flash may cause both elements to dredge up to the surface. In summary, our study contributes to a nuanced understanding of the roles played by the He-flash, lithium enrichment and chromospheric activity in shaping the evolutionary pathways of red giant branch stars, addressing the puzzle of high Li abundances observed in evolved giants.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

Probing Stellar Activity in Exoplanet Spectra with Hubble's STIS Instrument

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The Hubble Space Telescope has been a pioneer in studying exoplanet atmospheres for over three decades. However, with the emergence of the James Webb Space Telescope, a new era is dawning. JWST boasts advanced instruments delivering more precise data, potentially supplanting WFC3/IR observations over time. Nevertheless, there remains a crucial gap in optical wavelength coverage, a challenge that can be effectively addressed by the HST's STIS instrument. The optical spectrum is paramount to understand exoplanet atmospheres as it reveals vital information about the host star's activity and its impact on the planetary spectrum. In this context, we introduce a new, fully automated HST/STIS pipeline, designed for systematic and consistent data reduction across a broad range of exoplanet atmospheres. Covering the critical 0.3 to 1.1 um range, STIS data complements existing WFC3 and JWST observations. We present the pipeline's performance, showcasing STIS transit observations across a diverse sample of exo-atmospheres. Additionally, we demonstrate how our state-of-the-art retrieval technique is capable of disentangling the stellar signal from the planetary spectrum. This study reveals the necessity of accounting for stellar contamination in exoplanet transit studies and offers a catalogue of potential active targets for further investigation by upcoming stellar surveys in anticipation of the next-generation exoplanet missions.

Theme(s): Cool Stars as Stellar Systems

Observations of spiral and streamer on a candidate proto-brown dwarf

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Spirals and streamers are the hallmarks of mass accretion during the early stages of star formation. We present the first observations of a large-scale spiral and a streamer towards a very young brown dwarf candidate in its early formation stages. These observations show, for the first time, the influence of external environment that results in asymmetric mass accretion via feeding filaments on to a candidate proto-brown dwarf in the making. The impact of the streamer has produced emission in warm carbon-chain species close to the candidate proto-brown dwarf. Two contrasting scenarios, a pseudo-disc twisted by core rotation and the collision of dense cores, can both explain these structures. The former argues for the presence of a strong magnetic field in brown dwarf formation while the latter suggests that a minimal magnetic field allows large-scale spirals and clumps to form far from the candidate proto-brown dwarf.

Theme(s): New Insights into Star Formation and Evolution, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

Characterizing the Serpens S68N protostar photosphere with JWST/NIRSpec IFU spectroscopy

Ben Lew

Low-resolution spectral indices to derive M-dwarf abundances using wide binary systems

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M-type dwarf stars play an important role in contemporary stellar astrophysics, influencing diverse areas such as the Galactic chemical evolution and the characterisation of exoplanetary systems. Despite their significance, the determination of the chemical composition of these stars remains challenging due to the complex nature of their spectra, rich in prominent molecular features compared to solar-type stars. Our research aims to investigate the metallicity and elemental abundances of M dwarfs using 192 wide physical multiple systems composed of an F-, G-, or K primary star paired with an M-dwarf companion. We characterised the FGK primaries using HERMES high-resolution spectra, deriving abundances for 15 chemical elements. Assuming a common chemical composition within the components of the binary systems, we developed a novel methodology to infer calibrations for estimating the abundances of M dwarfs from CAFOS low-resolution spectral indices. By employing projection predictive feature selection and Bayesian inference, these calibrations demonstrate robust predictive performance, yielding abundance estimates with scatters ranging from 0.09 to 0.15 dex. Finally, we applied these calibrations to derive abundances for more than 770 M dwarfs observed with CAFOS, producing reliable results consistent with photometric estimations of metallicity and observed Galactic trends.

Theme(s): New Insights into Star Formation and Evolution, Cool Stars as Stellar Systems

High-Resolution Spectroscopy of 1RXSJ034231.8+121622 Confirms That The Companion is a Low-Mass Star

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The 1RXS J034231.8+121622 system consists of an M dwarf primary and a directly imaged companion. We use high resolution spectroscopic data from Keck/KPIC to estimate the objects' atmospheric parameters and radial velocities (RVs). Using PHOENIX stellar models, we find that the primary has a temperature of 3460 \pm 50 K a metallicity of 0.16 \pm 0.04, while the secondary has a temperature of 2510 \pm 50 K and a metallicity of 0.13\substack{+0.12 \\ -0.11}. Recent work suggests this system is associated with the Hyades, placing it an older age than previous estimates. Both metallicities agree with current [Fe/H] Hyades measurements (0.11 -- 0.21). Using stellar evolutionary models, we obtain significantly higher masses for the objects, of 0.30 \pm 0.15 M_\odot and 0.08 \pm 0.01 M_\odot (84 \pm 11 M_{Jup}) respectively. Using the RVs and a new astrometry point from Keck/NIRC2, we find that the system is likely an edge-on, moderately eccentric (0.41\substack{+0.27 \\ -0.08}) configuration. We also estimate the C/O ratio of both objects using custom grid models, obtaining 0.42 \pm 0.10 (primary) and 0.55 \pm 0.10 (companion). From these results, we confirm that this system most likely went through a binary star formation process in the Hyades. The significant changes in this system's parameters since its discovery highlight the importance of high resolution spectroscopy for both orbital and atmospheric characterization of directly imaged companions.

Theme(s): Cool Stars as Stellar Systems, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

The diversity of cold worlds: a spectral binary straddling the T/Y transition

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(1) Amherst College; (2) American Museum of Natural History; (3) CUNY; (4) University of Hertfordshire; (5) UT Austin; (6) UCSC; (7) Caltech; (8) Trinity College Dublin; (9) U. Montreal; (10) Backyard Worlds: Planet 9 Collaboration; (11) NSF's NOIRLab; (12) NASA Goddard; (13) NASA JPL; (14) IPAC/Caltech; (15) UCSF

We present the spectral binary modeling of WISE J014656.66+423410.0, the coldest, blended-light brown dwarf binary straddling the T/Y transition. We obtained a R\sim2700 moderate resolution prism spectrum with JWST/NIRSpec and we fit it to spectral binary templates and models. We find that this tightly-separated binary is likely composed of two unequal-brightness sources with a magnitude difference of 0.50\pm0.08 mag in absolute [4.5] and the secondary 1.005\pm0.125 mag redder than the primary in [3.6]-[4.5]. According to a binary model fit, the Disequilibrium chemistry shape the MIR spectra of these sources, as indicated by the best fit spectral template and models. While a larger library of JWST/NIRSpec spectra is needed to conclusively examine the peculiarities of blended-light spectra, this spectral binary is a crucial pathfinder to understand the spectral features of planetary atmospheres at high resolution and extremely cold temperatures.

Theme(s): Cool Stars as Stellar Systems, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

Photometric activity cycles in fast-rotating stars: Revisiting stellar activity cycle branches

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We aim to detect 11-year solar cycle-like activity cycles in young stars by combining photometric survey data, providing insights into how cycle periods correlate with rotation rates in fast-rotating stars. We measured activity cycles for 65 and 68 main-sequence stars using combined time-series photometry spanning ~14 years from, respectively, ZTF–ASAS-SN–Kepler-FFIs (Full Frame Images) and ZTF–Kepler-FFI data. Additionally, we measured activity cycles for 25 RS CVn candidates. We also identified whether observed flux variations correlate or anti-correlate with photospheric activity caused by the presence of faculae or starspots. We found that fast-rotating G–K dwarfs exhibit activity cycle periods of $\langle P\text{cyc}\rangle$ ~ 6–7 years, similar to slowly-rotating stars (Prot > 15–20 days), indicating no clear correlation between cycle length and rotation period. Previous studies have identified two distinct, linear branches in the cycle–rotation diagram – active and inactive branches. However, our samples do not exhibit any clear trend aligned with the active branch, with many stars falling in the intermediate region between the two branches. Moreover, we detected faculae-dominated fast-rotating K dwarfs. Our results highlight that for young main-sequence stars, the proposed distinction between the two branches may not be as definitive as previously thought, particularly regarding the active branch. Moreover, our Sun, which is positioned in the intermediate region, may not be peculiar.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

The impact of energetic particles on the atmospheres of exoplanets orbiting cool stars

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Energetic particles, such as stellar energetic particles and Galactic cosmic rays, are the high-energy component of space weather for exoplanets. Similar to UV, energetic particles can drive disequilibrium chemistry in exoplanet atmospheres. Warm gas giant atmospheres are likely to be the best JWST targets to detect the chemical signature of energetic particles in exoplanet atmospheres. The number of energetic particles reaching an exoplanet is needed to then study the chemistry caused by energetic particles. I will present our results that modelled the number of energetic particles reaching the mini-Neptune, GJ436 b. I will show how the energetic particles then lose their energy as they travel through the exoplanet atmosphere. I will discuss how, in the region of the atmosphere likely probed by JWST, stellar energetic particles dominate over Galactic cosmic rays. Our energetic particle fluxes can be used to model the chemical effect of energetic particles in exoplanet atmospheres. Detecting the chemical signature of energetic particles in an exoplanet atmosphere will give us a new window into exoplanet atmospheres. The thick hydrogen-dominated atmosphere of gas giant atmospheres is similar to a transient atmosphere that Earth could have had after a moon-sized impact. These oxygen poor conditions are good conditions for prebiotic molecule formation. I will also present our recent results looking at the transport of energetic particles in this type of early Earth atmosphere.

Theme(s): Cool Stars as Stellar Systems

Are the metal-poor M dwarfs in the solar neighborhood actually from our neighborhood?

Diogo Souto

Probing stellar rotation between 45 Myr and 2.7 Gyr using NGTS clusters data

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We present rotation periods (P_{\rm rot}) for 3 clusters from the NGTS survey. The candidate selection are drawn from the NGTS fields with astrometric bounds constructed from Gaia DR3 based on a joint membership list by [1] and [2]. The rotation is derived homogeneously using mainly Autocorrelation Functions, and the Lomb-Scargle periodograms. Visual inspections as well as binary filters (e.g, Gaia [3] RUWE and astrometric excess noise and CMD fitting) were carried out to enforce a high purity in our sample (Fig.1a). We compared our sample with the literature where agreement was achieved for the majority of our stars. However, ~10% had either systematics or blends from TESS, which from NGTS had a clear detection given its ~1 year baseline and 5” pixel scale, respectively. Finally, Fig. 1b shows the rotation distribution as a function of age, where Gyrochronology models will be calibrated as part of this work.

Theme(s): The Sun and Cool Stars in the Time Domain

Unraveling The Atmospheric Impact of Clouds using Benchmark Brown Dwarf Systems

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In the era of JWST, it is now possible to look into substellar mass atmospheres in unparalleled detail and precision. However, unraveling the complicated dynamics and chemistry in these atmospheres remains a challenge. Atmospheric retrievals are a leading data-driven tool capable of recovering an object’s fundamental parameters such as mass, effective temperature, cloud structure and composition and chemical abundances. However, in directly imaged or isolated worlds, constraining and/or interpreting these fundamental parameters can be difficult, particularly considering the overall impact of clouds. In this work, we turn to main sequence star – brown dwarf companion systems where the main sequence host can anchor metallicity, age, and abundance measurements for its substellar companion. We present results from conducting theoretical chemical analyses on a sample of benchmark companions as well as solar neighborhood F, G, K-type stars to provide a global overview of the types of chemistry we might expect in nearby objects. We predict the amount of oxygen that is being sequestered into refractory condensates in substellar atmospheres based on stellar abundances of Mg, Si, Ca, Al and O. Additionally, we use solar neighborhood Mg/Si ratios to predict silicate condensation species (i.e. enstatite (MgSiO_3), forsterite (Mg_2SiO_4), and/or quartz (SiO_2)) in a given companion. This talk aims to discuss this work in detail and highlight the importance of studying companion systems.

Theme(s): Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

Chemodynamics of 109,276 local M-Dwarfs From Improved SDSS Metallicity Classification Templates

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An examination of 109,276 optical spectra of low-mass stars in the Sloan Digital Sky Survey (SDSS) provides a broad collection of long-lived objects in the Solar Neighborhood that traces the three major components of our Galaxy: the thin disk, the thick disk, and the halo. These populations have distinct metallicities and kinematics that differentiate them from one another. One complication is that measuring metallicities of M-dwarfs from mid-resolution spectroscopy or photometry alone remains a challenge, even with the availability of Gaia data. To better characterize these low-mass stars, we use a set of 536 improved, empirical K and M dwarf spectral templates to more accurately determine spectral subtypes and metallicity classes for each of the stars in our sample. We fit each template to an individual spectrum, covering a range of 5000-8000 Å, and select the best fit templated based on the minimum $\chi 2$ value. We confirm the most metal-rich stars are located primarily in the thin disk and we observe the known effect radial metallicity migration. The confirmation of these chemodynamic trends validates the improved templates developed in this work. We are also able to see structure in the metallicity gradient of the most metal-poor stars and begin to distinguish between Gaia-Enceladus merger stars and true halo objects. This methodology opens the door to use the dominant population of local M-Dwarfs to trace chemodynamics in the Solar Neighborhood.

Theme(s): Milky Way-scale Science and Big Data, Cool Stars as Stellar Systems

Magnetic variability and exoplanet detection thresholds for the young solar analogue V889 Her

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Discovering exoplanets orbiting young Suns can provide insight into the formation and early evolution of our own solar system, but the extreme magnetic activity of young stars obfuscates exoplanet detection. This poster presents the results of the long-term monitoring of the magnetic field and chromospheric activity variability of the young solar analogue V889 Her, and evaluates the impacts of extreme magnetism on exoplanet detection thresholds. We measured Ca H&K activity and reconstructed the large-scale magnetic field for 14 epochs between 2004 and 2019 using spectropolarimetric observations taken with the Telescope Bernard Lyot, 3.6-m ESO Telescope and the Anglo-Australian Telescope. Our results show that the large-scale magnetic field of V889 Her may undergo 3-4 yr fluctuations, evolving from weak and simple during

chromospheric activity minima to strong and complex during activity maxima, but without any polarity reversals. Using Doppler Imaging to filter activity jitter from the stellar radial velocity, we estimate that we could detect Jupiter-mass planets with orbital periods of ~3 d.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

In search of accurate indicators for stellar parameter determinations in very cool M dwarfs

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Accurate parameter determinations (effective temperature, surface gravity, and metallicity) from stellar spectra in very cool M dwarfs (M7.0 V and beyond) still prove extremely elusive, mostly due to the absence of useful line indicators used in early M dwarfs and the impact of stronger molecular absorption bands that severely disrupt their spectra. Additionally, the presence of more intense magnetic fields and violent activity phenomena make such determinations even more challenging. However, these accurate parameter determinations are still essential to better characterize the exoplanetary systems discovered around very cool M dwarfs: for instance, the M8.0 V exoplanet host star TRAPPIST-1 or the M7.0 V host Teegarden's Star. In this contribution, we expand the methodology used by Marfil et al. (2021), based on spectral synthesis, to characterize the coolest M dwarfs observed with CARMENES. We delve into the selection of the most reliable spectral indicators for stellar parameter determinations in a collection of very high-resolution (R=90,000), high signal-to-noise spectra in the optical and near-infrared wavelength regions (520-1710 nm). We employed a new grid of atmospheric models called NewEra (Hauschildt et al. in prep.), which introduces significant improvements to previous grids, such as updated molecular line lists. To validate such analysis, we compared the results obtained with the analysis done by Marfil et al. (2021) for the CARMENES M-dwarf GTO sample.

Theme(s): Cool Stars as Stellar Systems, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

Simulating Solar Neighborhood Brown Dwarfs: A Guide for Upcoming Surveys

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Major upcoming digital sky surveys will reveal unprecedented numbers of brown dwarfs, among even greater numbers of stellar objects, enabling the statistical study of brown dwarfs. To effectively parse these massive datasets and extract the comparatively rare brown dwarfs, we must understand how brown dwarfs will look in upcoming databases. To explore the photometric properties and spread of brown dwarfs, we construct a synthetic population of brown dwarfs in

the Solar Neighborhood using Gaia-derived star formation rate histories and Galactic thin disk scale heights alongside observational mass, metallicity, and age relationships. We apply the Sonora Bobcat and the 2008 Saumon and Marley hybrid (SM08) evolutionary models to assign temperatures, luminosities, and radii to the sample. We present luminosity, temperature, age, and metallicity functions varying with height above the Galactic thin disk. These models predict significant differences in the brown dwarf population as a function of distance from the Galactic plane, which can be tested with future JWST, Rubin Observatory LSST, and Roman surveys.

Theme(s): Milky Way-scale Science and Big Data, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

The SOL (Solar Origin and Life) Project: Detailed characterization of Solar analogs at ZAMS

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The solar situation in the galactic neighborhood is not well understood, especially when we compare its physical properties with those of nearby stars. Thereby, we still cannot fully understand whether or not the Sun is a typical star. This is due to recent results in the literature that support both hypotheses. Therefore, this work aims to identify and characterize stars that could represent the Sun at the ZAMS stage. We performed a precise spectroscopic analysis of the candidates using high-resolution (R ~ 35000 - 115000) and signal-to-noise (S/N > 150) spectra obtained with modern instruments (HARPS/ESO, HIRES/KECK, for instance). We adopted the classical spectroscopic method and derived evolutionary parameters (mass, radius, luminosity, and age), using theoretical evolutionary tracks and isochrones. We also performed age estimates through 2 additional independent methods and we present the chromospheric activity levels of our candidates. We identified 2 candidates (HD 13531 and HD 61033) capable of representing the Sun at the ZAMS stage. Moreover, 2 stars (HD 64114 and HD 197210) could be interesting for studying the Sun with ~2 Gyr, when the Earth's atmosphere started having a significant amount of oxygen. We aim to expand our sample using GAIA photometric data, selecting new star candidates for the ZAMS stage. We also expect to increase the number of Sun analogs by a great factor and we would like to submit them as high priority targets for exoplanet searches.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

Towards comprehensive characterization of benchmark brown dwarfs

Emily Rickman (1); William Balmer (2); Laurent Pueyo (3); William Ceva (4); Elisabeth Matthews (5); Damien Ségransan (4)
ESA/STScI; Johns Hopkins University; STScI; University of Geneva; MPIA

Understanding the formation and atmospheric properties of giant planets and brown dwarfs is a major goal of modern astrophysics. Measurements of companion brightness, atmospheric parameters and dynamical environments require direct observations but face the difficulty of low detection efficiency. With JWST as well as upcoming facilities like the ELT and the Roman Space Telescope, observing time is valuable and the strategy of direct imaging needs to be re-defined to pre-select targets and characterize the companions that we do discover. To utilize the power of high-contrast imaging and to increase the detection efficiency of these observations, pre-selecting companion candidates with long-period radial velocities, coupled with astrometry from Hipparcos and Gaia, provide a powerful tool to hunt for the most promising candidates for direct imaging. Not only does this increase the detection efficiency, but this wealth of information removes the degeneracy of unknown orbital parameters leading to derived dynamical masses that serve as benchmark objects to test models of formation and evolution. Through this method, we have revealed a precious sample of benchmark brown dwarfs that span spectral types, with known ages and dynamical masses that make them key laboratories to study atmospheric and evolutionary models. The comprehensive characterization of these objects enables us to test models of the formation, evolution and atmospheric properties of giant planets and brown dwarfs.

Theme(s): Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

Low-latitude emergence of starspots on fast rotators

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Rapidly rotating solar-type stars are known to be dominated by high-latitude and polar spots. This is consistent with models of buoyantly emerging magnetic flux tubes through convection zones, undergoing strong poleward deflection by the Coriolis effect. However, many (Zeeman-)Doppler (ZD) images of fast rotators also show magnetic features near the equator, around one or more longitudes at the same time. Forward-modelled Doppler images of EK Dra indicated that they could be artefacts of opposite-hemisphere activity under specific conditions. However, low-latitude spots seem to be ubiquitous in independent (Z)D reconstructions of many fast rotators. Here, we propose a mechanism leading to exceptionally buoyant flux loops that end up at latitudes below \pm10 degrees, for a solar-type convection zone with a surface rotation period of 3 days. In this scenario, flux tubes stem from a range of initial depths and field strengths below the base of the convection zone, where the deepest and strongest tubes starting near the equator obtain sufficient buoyancy, thereby emerging at low latitudes.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

AstroCatalyst: Economic Returns and Educational Impact of Astronomical Phenomena

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The intersection of astronomical phenomena and economic development offers a unique perspective on the benefits of investment in astrophysical research. We start by exploring the dual impact of the latest astronomical events, such as the total solar eclipse of April 2024, on local economies in the US. The aim is to create a research framework and gather data of quality, to develop a methodology to assess economic benefit as well as large public engagement, awareness of astronomical events, and perceptions towards STEM subjects in young audiences from different backgrounds. We are scientists and economists interested in preserving the quality of our skies, engaging large audiences with astrophysical events, and understanding their impact on local economies and educational engagement. Our focus includes the benefits for all stakeholders and the influence on young students' perceptions and engagement in STEM subjects, with particular attention to women and minorities. Finally, to make a more equitable profession we are required to understand the full impact of astronomical phenomena.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

The substellar neighborhood: a stunningly diverse population of brown dwarfs

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The census of the coldest constituents of the Solar Neighborhood remains incomplete. Completing such census is one of the driving goals for the CatWISE and "Backyard Worlds: Planet Nine" teams, who have discovered hundreds of new late-T and Y dwarfs using data from WISE/NEOWISE. In this poster we present the results of our on-going observing campaign, which is revealing a stunning diversity among the substellar population, a diversity that atmospheric models suggest is driven by metallicity.

Theme(s): Cool Stars as Stellar Systems, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

Detailed cool star flare morphology with CHEOPS and TESS

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White-light stellar flares are proxies for some of the most energetic types of flares, and can inform us about the high-energy irradiation environment that exoplanets live in. We used 3-s cadence CHEOPS and 20-s cadence TESS light curves to study the morphology of white-light flares in a sample of 130 late K and M stars, particularly by resolving the components of multi-peak outbursts. To do this, we developed a software which is now becoming a part of the flare-finding search algorithm in the data analysis pipeline for the PLATO mission. Our findings suggest that high-impulse flares are more frequent than suspected from lower-cadence data, so that the highest flux values hitting close-in exoplanets might be more time-limited than expected. We found significant differences in the duration distributions of single and complex flare components, but not in their peak luminosity. A statistical analysis of the flare parameter distributions provides marginal support for their description with a log-normal instead of a power-law function, leaving the door open to several flare formation scenarios. We also present preliminary results for a parallel search for stellar granulation signals – still undetected in late K and M dwarfs - in the same stellar sample, using exquisite CHEOPS photometry.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

Library of Inferred Extreme Ultraviolet Spectra I: Main Sequence Stars Observed by EUVE

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We are assembling a library of extreme ultraviolet spectra (LIEUVS) for GKM dwarfs, inferred using the differential emission measure (DEM) technique applied to all such stars where sufficient Hubble far ultraviolet (FUV, 912 -- 1700 Å) and Chandra/XMM-Newton X-ray (1 -- 100 Å) data exist. Stellar emission in the extreme ultraviolet (EUV) regime, from 100 -- 912 Å, is a major factor in planetary evolution as a driver of atmospheric escape, but observations of main-sequence stars at EUV wavelengths are scant due to a lack of operational facilities with the sensitivity to measure enough of the photons that make it through the local interstellar medium. The DEM is a simple structural model of the upper stellar atmosphere that can be constrained using measured FUV and X-ray emission and then combined with atomic data to infer the unobserved but co-spatially formed stellar EUV spectrum. This work is the first release from LIEUVS: demonstrating the technique and data products for the few main-sequence stars

where we can both inform and test the method with spectra from the Extreme \ Ultraviolet \ Explorer (EUVE, 1992 -- 2001).

Theme(s): The Sun and Cool Stars in the Time Domain

UX Mense: A Detached Eclipsing Binary as a Benchmark candidate for ESA's PLATO mission

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Detached eclipsing binaries (DEBs) with radii and masses with precision below 1 percent are poised to serve as benchmark stars for forthcoming space missions, like ESA's PLATO mission. These DEBs provide a reliable standard for stellar parameter determination, particularly enhancing the accuracy and precision of radii and masses. A Benchmark candidate was observed from TESS in a continuous observing zone spanning over 31 sectors coupled with multi-epoch radial velocities. Our project involved estimating stellar parameters through light curve and radial velocity modelling across each sector using diverse modelling codes. We uncovered an inconsistency in achieving sub-percent precision, significantly influenced by stellar activities. Additionally, atmospheric parameters were derived via spectral disentangling with a focus on ensuring consistency between photometric and spectroscopic effective temperature estimates. Furthermore, we are investigating the repercussions of minute uncertainties in stellar parameters on stellar ages. The study emphasizes the critical role of precise parameter determination, highlighting its substantial impact on determining stellar ages accurately. By exploring variations in parameter space, we aim to shed light on the effects on stellar age determination, contributing to a deeper understanding of stellar evolution and astrophysical processes.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

Coronal imaging and X-ray activity cycles of an ultra-fast rotator star, AB Dor

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By utilizing extensive long-term X-ray observations, we conduct a thorough analysis of the short-term and long-term variability in X-ray emissions from the ultra-fast rotating active star AB Dor. Our analysis reveals that flaring events are common occurance, averaging at approximately 57±23% of the observation time is affected by flares. During flare-free periods,

the X-ray light curves exhibit rotational modulation, indicative of the presence of highly active regions within the star's corona. Using a novel light curve inversion code, we undertake coronal imaging to find the structure of these active regions. Our results demonstrate the existence of two distinct active regions with varying brightness, separated by approximately 180 degrees in longitude. Moreover, these active regions display longitudinal migration and brightness fluctuations over time. Analyzing X-ray data spanning from 1979 to 2022, we identify multiple periodicities. Notably, we observe a cycle with a period of approximately 19.2 years, its first harmonic, suggestive of a Solar-like long-term activity cycle. Additionally, periodicities of approximately 3.6 and 5.4 years are indicative of a flip-flop cycle in X-rays, consistent with previous optical observations.

Theme(s): The Sun and Cool Stars in the Time Domain

The INT Survey of Local Group Dwarf Galaxies VIII, The SFH and DPR of Andromeda Dwarf Satellites

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An extensive analysis of observed spheroidal dwarf satellites of the Andromeda galaxy was conducted to provide a comprehensive catalog of LPV stars. The study is part of a optical monitoring survey to observe 55 dwarf galaxies and four globular clusters within the Local Group. The dwarfs were observed using the wide field camera of the 2.5 meter INT. These observations were conducted through a near-infrared and an optical bands at nine epochs. Our focus is on detecting AGB stars when their magnitude amplitude becomes higher than 0.2 mag to track dwarf evolution. In dwarf galaxies, LPV stars provide powerful tools for reconstructing the SFH. LPV stars are suitable for study due to the relation between their birth mass and luminosity at the end of their evolution. Star formation scenarios could also be studied by comparing the age gradient of variable stars between two half-light radii. This study also provides estimates of satellite characteristics such as the half-light radius, the RGB-tip, the distance modulus, the quenching time, and the total stellar mass. Our work is extended by estimating the mass-loss rates to produce dust maps for each dwarf. Mass-loss of LPVs contributes to galaxy chemical enrichment and SF. It is also possible to estimate the re-ignition time for SFH by calculating the total mass return of LPVs. Additionally, the distance modulus has been updated using RGB-tip through the tip detection of the Sobel filter in this study.

Theme(s): New Insights into Star Formation and Evolution

New Stellar Activity Cycles of FGK stars from the California Legacy Survey on Keck/HIRES

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We present optical spectroscopy of 710 solar neighborhood stars collected over twenty years to catalog chromospheric activity and search for stellar activity cycles. The California Legacy Survey stars are amenable to exoplanet detection using precise radial velocities, and we present their Ca II H andK time series as a proxy for stellar and chromospheric activity. Using the HIRES spectrometer at Keck Observatory, we extract stellar flux in the cores of the Ca II H andK lines to determine Mt. Wilson style S-values and the log(R`HK) metric, which is comparable across a wide range of spectral types. From the 710 stars, with 54303 observations, 284 stars are amenable to searches for stellar activity cycles with periods of 2--25 years, and 113 stars show stellar cycles of varying length and magnitude. These observations may be used to disentangle the effect of stellar magnetic activity when measuring exoplanet masses. We use them to place the Sun's stellar magnetic activity into context of the stellar activity in the solar neighborhood, and present the largest sample of stellar activity cycles to date.

Theme(s): New Insights into Star Formation and Evolution, The Sun and Cool Stars in the Time Domain

Pulsation-Induced Fluctuations in Mass-Loss Rates of AGB Stars

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Our research identified a correlation between the mass-loss rates of AGB stars and their near-infrared (NIR) colors during pulsations. Initially, we estimated the relationship between NIR color and mass-loss rate for AGB stars. This relationship exhibits slight differences between Galactic AGB stars and those in the Magellanic Clouds. NIR monitoring observation data indicate that NIR colors change during pulsations. Based on these findings, we determined that: 1) there is a strong correlation between NIR color and variations in mass-loss rate, and 2) long-period AGB stars experience greater changes in mass-loss rates compared to short-period ones during pulsations. This suggests that long-period AGB stars exhibit more dynamic behavior than the short-period ones.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

The Enigma of Li-Rich Giants and its Relation with RV and Stellar Activity Variations

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Much of what makes a star lithium rich is still a mystery. Magnetic activity, in particular the phenomena usually associated with it, and the lithium abundance of stars are in general thought to be connected. However as of today, it is unclear just how. In this work, in hopes of shedding light on this conundrum, we study a sample of young but evolved intermediate mass red giants, some of which are lithium rich, in open clusters where planets have been searched. We make use of radial velocity and stellar activity signals to look for relations between the variations observed and the surface lithium abundance of these stars. We find that the measurements of dispersion of the stellar activity signals increase exponentially with the lithium abundance of the stars in our sample. To strengthen our analysis we also look for correlations as well as periodic temporal variations in stellar activity signals that may connect variability observed in radial velocity to stellar activity. High correlations also tend to be found preferentially for stars with higher lithium abundances. Interestingly, we also find that most of the lithium rich giants in our sample either show strong correlations between radial velocity measurements and at least one of the stellar activity indicators considered or reveal periodic variability in these signals. This work thus provides evidence that red giants with higher lithium abundances are also more magnetically active.

Theme(s): Cool Stars as Stellar Systems

Probing Accelerated Particles in Flares from AU Mic Using Optically Thin Radio Data

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The flares of M-dwarf stars are becoming increasingly important to understand, as they may affect the habitability of exoplanetary systems. Physical models are powerful tools to estimate these impacts, but more multiwavelength studies are needed to justify assumptions used when extrapolating between wavelengths. Using data from a 7-day observational campaign of the young, active dM1e star AU Mic, we previously measured the thermal empirical Neupert effect (ENE) in the near-ultraviolet and soft X- ray regimes for 46 multiwavelength flares (Tristan et al. 2023, ApJ). Here, we add simultaneous Ku-band radio observations (12~18 GHz) from the Jansky Very Large Array (JVLA) with preliminary analysis on gyrosynchrotron fluxes, flaring energies, and polarization changes for at least 6 of these flares. As the Ku band is in the optically thin part of the flaring spectrum, we also discuss the accelerated power-law spectral indices and constraints on the kinetic energies of the radiating electrons. While many flares (~65%) from AU Mic do not follow the thermal ENE, this radio dataset will test the ENE using nonthermal emission and evaluate the use of a thermal proxy. At least one flare shows no discernible response in other bands. We discuss the implications for physical possibilities that could influence M dwarf flare modeling. Future work will add temperatures from X-ray spectral analysis to continue characterizing physical parameters, like loop size and total electron density.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

M Dwarfs from the Bottom Up: SPHINX M Dwarf Structure and Evolution

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M dwarfs make up >70% of all stars. For decades, M dwarf evolution models have had heritage in the methods of higher mass stars, but their molecule-dominated atmospheres and partially degenerate interiors share a greater kinship with brown dwarfs and giant planets. Past modeling work has resulted in poor constraints on fundamental properties of M dwarfs and inaccurate assessments of the hydrogen-burning limit. However, recent state-of-the-art models of the molecule-rich atmospheres of these stars using methods first used in brown dwarfs and ultra-hot Jupiters, and a reassessment of the dense interior equation of state, present an excellent opportunity to close gaps between models and observations of M dwarfs. We present our latest work, which integrates new atmospheric boundary conditions from SPHINX model atmospheres into the MESA and Sonora codes for self-consistent M dwarf structure and evolution modeling.

Theme(s): Cool Stars as Stellar Systems, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

Know your little neighbours: M dwarfs and planets in the Solar neighbourhood

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Most stars in our immediate neighbourhood are not like the Sun. The largest (by number) stellar population in the solar neighbourhood is constituted by low-mass (or M dwarfs) stars. At the same time, M dwarfs have been recognised as important targets for exoplanet surveys. However, unlike their solar-type counterparts, the stellar properties of M dwarfs are poorly constrained. In this contribution, we will show how the uncertainties in the stellar parameters of M dwarfs host stars have a significant impact in the determination of the planetary bulk composition and discuss recent approaches to determine the stellar parameters and abundances of M dwarfs: from the use of pseudo-equivalent widths to dimensionality reduction and sparse Bayesian methods. Finally, we will discuss the demographics of exoplanets orbiting around M dwarfs as a function of the properties and environmental conditions of the host stars (mass, iron content, and chemical abundances).

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

Cooling Evolution of Low Luminosity Objects (CELLO): New Hybrid Models for Young Substellar Objects

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We present new evolutionary models (CELLO) for very-low-mass brown dwarfs and planetary-mass-objects with surface boundary conditions that include a cloudy-clear transition at effective temperatures of 1100K. This work is motivated by the excess of brown dwarfs in the solar neighborhood with effective temperatures of ~1300K, a feature is predicted only by the hybrid cloudy-clear evolutionary models of Saumon and Marley (2008), and the widespread evidence that the L/T transition occurs at lower effective temperatures for low surface gravity objects. Our model family includes hot, warm, and cold start initial conditions suitable for both “star-like” and “planet-like” formation scenarios. We show that significant effects are present for ages <200 Myr and that including the cloudy-clear transition is particularly important for objects just above the deuterium-burning limit.

Theme(s): Cool Stars as Stellar Systems, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

VLBI astrometry and polarized radioemission from a very cool brown dwarf

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The nearby T6 brown dwarf 2MASS J11225550+2550250 (EQ1122+2550) is known to have radio emission resulting from an extraordinary fast rotation. Recent VLBI observations show the presence of compact radio emisión, making EQ1122+2550 one of the coolest objects accesible by VLBI techniques. The mass of EQ1122+2550, well below the substellar limit (30 Mjup), and the presence of compact radio emission convert this object in a primer target for exoplanet searches. We report on a EVN/VLBA astrometric monitoring of EQ1122+2550, sensitive to planets with a mass similar to Saturn as close as 0.3 au. The variability and polarization of the EQ1122+2550 radio emission may be explained in terms of auroral electron cyclotron maser emission from Jupiter-like ring structures located near the magnetic poles.

Theme(s): Cool Stars as Stellar Systems, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

Fluorine Abundances in Carbon Stars

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We determine the abundance of fluorine in ten Galactic carbon stars (2 N-type, 6 R-type, and 2 J-type) with C/O ratios \geq1.1 using spectra obtained with the high-resolution spectrograph iSHELL (R\sim75,000) on the 3-meter NASA InfraRed Telescope Facility (IRTF). Abundances are determined from the (2-0) R9 2.3358 μm feature of the HF molecule. No significant fluorine enhancements are observed in our sample of carbon-rich stars. Possible moderate enhancements are observed depending on the type of model atmosphere used. The R stars in our sample may reflect the trends of the galactic evolution of fluorine better than the [F/Fe] ratios anticipated from TDU events. The observed J-type stars have low F abundances for their C/O ratios compared to N-type carbon stars. Additionally, they have lower F abundances than their potential precursors, the R-type stars. We derive the fluorine abundance for the low-metallicity ($-2 <$ [Fe/H] < -1) carbon star HD 189711 ([Fe/H]=-1.15) of [F/Fe] = 0.89, which agrees with model predictions at low metallicity.

Theme(s): New Insights into Star Formation and Evolution, Cool Stars as Stellar Systems

The Artemis-enabled Stellar Imager (AeSI): A Lunar Long-Baseline UV-Optical Imaging Interferometer

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NASA's return to the Moon presents a unique opportunity to pursue high impact scientific capabilities, such as high angular-resolution ultraviolet/optical interferometric imaging. This can resolve the surfaces of stars, probe the inner accretion disks surrounding nascent stars and black holes, and pave the way for resolving surface features and weather patterns on the nearest exoplanets. We have been awarded NASA Innovative Advanced Concepts (NIAC) Phase 1 support to investigate the details of building a high-resolution, long-baseline, UV/optical imaging interferometer (AeSI) on the lunar surface in conjunction with the Artemis Program. A 1996 study compared interferometers on the moon vs. free-flyers in space and concluded that without a pre-existing lunar infrastructure, free-flyers are favored. With the Artemis Program and its lunar infrastructure, moon-based interferometers now deserve a closer look. Our goals are to provide the same level of detailed study as was done for large baseline, free-flying interferometers during the 2003-2005 NASA Vision Missions Studies, such as done for the Stellar Imager (SI), and to determine the relative merits of the moon-based vs. free-flyer versions. This concept study will be a huge step forward to larger arrays on both the moon and free-flying in space, over a wide variety of wavelengths and science topics. Our Phase 1 study began in April 2024 and here we present a concise overview of our vision and the progress made so far.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

Accretion of Pre-Main Sequence binaries

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The magnetospheric accretion of classical T Tauri stars is now better understood. In these systems, the inner disc is truncated by the strong magnetic field of the star, forcing the material to leave de disc plane and free-falling onto the stellar surface following the magnetic field lines. However, this process is valid only for single stars, a companion or a circumbinary disc doubtless implies deviations from this scheme. In this talk, I will present a spectropolarimetric analysis of extreme cases of this situation: Eccentric binaries with equal-mass components accreting from a circumbinary disc. This study aimed to identify if the accretion of these systems can be interpreted as a single-like case with some deviations. We thus looked for signatures of magnetically driven accretion, along the rotation cycle of the components and the orbital motion. We concluded that a magnetically driven accretion is in place on these systems as well. However, the inner disc might be too distant to be reached by the components' magnetic field, the materials are thus probably first brought closer by gravitational instabilities. In addition, we showed that the inter-cycle variations of the systems' accretion are at least partly shaped by the magnetic field variations of the components.

Theme(s): New Insights into Star Formation and Evolution, Cool Stars as Stellar Systems

A Possible Mechanism for "Late Phase" in Stellar White-Light Flares

Kai Yang

Revisiting Physical Parameters of the Benchmark Brown Dwarf LHS~6343~C Through an HST/WFC3 Eclipse

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The LHS 6343 system consists of a resolved M-dwarf binary with an evolved, negligibly irradiated brown dwarf, LHS 6343 C, orbiting the primary star. Such brown dwarf eclipsing binaries present rare and unique opportunities to calibrate sub-stellar evolutionary and atmosphere models since mass, radius, temperature and luminosity can be directly measured. We update this brown dwarf's mass (62.6 ± 2.2 MJup) and radius (0.788 ± 0.043 RJup) using empirical stellar relations and a Gaia DR3 distance. We use HST/WFC3 observations of an LHS 6343 C secondary eclipse to obtain a NIR emission spectrum of spectral type of T1.5 ± 1. We combine this spectrum with existing Kepler and Spitzer/IRAC secondary eclipse photometry to perform atmospheric characterization using the ATMO-2020, Sonora-Bobcat and BT-Settl model grids. ATMO-2020 models with strong non-equilibrium chemistry yield the best fit to observations across all modelled bandpasses. Finally, we obtain a semi-empirical measurement of LHS 6343 C's apparent luminosity by integrating its observed and modelled spectral energy distribution. Applying knowledge of the system's distance yields a bolometric luminosity of log(Lbol/Lsun) = −4.77 ± 0.03 and, applying the Stefan-Boltzmann law for the known radius, an effective temperature of 1303 ± 29 K. We also use the ATMO-2020 and Sonora-Bobcat evolutionary model grids to infer an age for LHS 6343 C of {2.86}^{+0.40}_{−0.33} Gyr and {3.1}1^{+0.50}_{−0.38} Gyr respectively.

Theme(s): Cool Stars as Stellar Systems, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

Stellar Rotation Rates in the Lagoon Nebula

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By understanding the rotation rates of young stars, we can learn about the star-disk interaction, accretion, planet formation, and the evolution of all of these things as a function of both age and mass. The Lagoon Nebula is a young (<1 Myr) star forming region with many O and B stars; it was observed by K2 in 2016. Venuti et al. (2021,2024) have explored the variability of young stars in general in this region using these high-precision light curves. We present here the distribution of rotation rates as obtained from K2 light curves, and explore the influence of disks on the rotation rates. We place the Lagoon nebula in context with the distribution of rotation rates from other young clusters (e.g., Taurus, UCL/LCC, Pleiades).

Theme(s): New Insights into Star Formation and Evolution, The Sun and Cool Stars in the Time Domain

Looking for star-planet interaction in the CARMENES M-dwarf sample with radio observations

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The interaction between an exoplanet and the incoming stellar wind is expected to induce auroral radio emission on the host star via the electron cyclotron maser mechanism, if the planet is located inside the Alfvén surface. This auroral emission has some distinct features: it varies rapidly with time, shows a high degree of circular polarization and periodic enhancements that depend on the orbital period of the planet. Detecting this particular emission would make radio observations a new and independent method for detecting exoplanets. The most common type of stars are M-dwarfs, which often host planetary systems. In many of these stars, their planets orbit so close to the star that they are well within the Alfvén surface, making them ideal candidates for detecting radio emission from star-planet interaction. Here, we present results from a series of radio campaigns with the VLA and the uGMRT, aimed at detecting star-planet interaction in nearby (d < 16 pc) stars from the CARMENES sample that host short-period (P_{\rm orb} < 7 days) planets. We will discuss the implications of our results within models of star-planet interaction, which constraints relevant physical parameters of those planetary systems.

Theme(s): Cool Stars as Stellar Systems, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

Rotational Evolution and Radii of Young Sun-like Stars in NGC 2264

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A major goal in astronomy is understanding the formation and evolution of our Solar System and that of other Sun-like stars and planetary systems. Investigating the angular momentum evolution of T Tauri stars provides important insight into the interactions between Sun-like stars

and their protoplanetary disks and the timescales that govern disk dissipation and planet formation. We present projected rotational velocities (v sin(i) values) of 220 T Tauri stars in the open cluster NGC 2264, measured using high-dispersion spectra from the WIYN 3.5m telescope's Hydra instrument. We combine these with literature values of temperature, rotation period, luminosity, disk classification, and binarity. We find some evidence that weak-lined T Tauri stars may rotate faster than their classical T Tauri counterparts with accreting disks and that stars in binary systems may rotate faster than single stars. We also use a maximum likelihood modeling technique to compare the projected stellar radii of our sample stars to the radii predicted by stellar evolution models. We find that starspot-free models tend to underestimate the radii of the PMS stars, while models that include starspot coverage are more successful. Our study of NGC 2264 serves as a pilot study for analysis methods that will be applied to four other clusters ranging in age from 1 to 15 Myr, the timescale over which the protoplanetary disk dissipates and planetary systems begin to form.

Theme(s): New Insights into Star Formation and Evolution, The Sun and Cool Stars in the Time Domain

Evolution of the polar starspot on the M-dwarf transiting planet, TOI-3884

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TOI-3884 is an M4-dwarf star with a transiting super Neptune planet in a 4.5~day orbit. A large persistent positive feature visible in multiple ground and space-based transit light curves is consistent with the planet in a misaligned orbit (\lambda = 75^\circ) crossing over a large, long-lived starspot on the south pole of the star. We present the STSP analysis of multi-band time series photometry of the spot crossing feature obtained with the ARCTIC instrument at the Apache Point Observatory over three seasons from 2022-2024. We derive the broad features of the polar spot in the path of the planet along and the out-of-transit spots that are consistent with these data. We also constrain the temperature of the large spot based on simultaneous multi-band photometry.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

Infrared Gold: Extraction and Dissemination of 20 Years of IRTF/SpeX Point-Source Spectroscopy

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We will present an overview of our program to reduce all point source observations taken with SpeX, a 0.8-5.5 micron low- (R~200) and medium-resolution (R~2000) spectrograph on the 3m NASA Infrared Telescope Facility. Since its commissioning in 2000, SpeX has generated over 1.7 million exposures (40 TB) of data for roughly 50,000 sources split nearly evenly between planetary and astrophysics sources. As a part of this program, we are converting SpeX's data reduction package Spextool, which was written in Interactive Data Language (IDL), to a Python package called pySpextool. The telluric-corrected and flux-calibrated spectra will be available for inspection and download at the Infrared Science Archive (IRSA) hosted by the Infrared Processing and Analysis Center (IPAC) at Caltech.

Theme(s): Milky Way-scale Science and Big Data, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

Eclipsing Binaries with low mass stars: Final results of our programme exploring radius inflation

M. I. Swayne

Superflare activity on the southern active binary CC Eri

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Superflares are a subject of interest for the last decade when the first statistical analysis of superflares was conducted. So far superflares have been observed spectroscopically recently in Halpha only and in the past very rarely. We present Echelle spectroscopic monitoring of the young and active southern dK+dM dwarf binary. More than 2000 spectra have been recorded summing up to 190 hours of on source time. The spectra have been obtained through the PlatoSpec consortium at the ESO1.52m on LaSilla, Chile. In addition to the spectroscopic monitoring, the ESO1.52m is capable of doing ccordinated g'-band photometry. We have detected so far 18 flares determined from Halpha equivalent width light curves and two from photometry. The two g'-band flares reveal superflare energies and one Halpha flare alone shows already superflare energies. We have identified several line asymmetries occuring during the flares from which we show two examples. We furthermore discuss preliminary results of comparative spectral line analysis between flares and superflares.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

MHD simulations of the space weather in Proxima b: Habitability conditions and radio emission

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We present PLUTO MHD simulations around the Earth-like exoplanet Proxima b, both under calm and extreme, CME-like space weather conditions. Our simulations allow us to characterize the magneto-plasma environment and thus the habitability of Proxima b, which lies inside the habitable zone of its host M-dwarf star Proxima. We also determine the radio emission arising from the interaction between the stellar wind of Proxima and the magnetosphere of its planet Proxima b, which is relevant to guide radio observations aimed at unveiling planets. Both habitability and radio emission critically depend on three main factors: the magnetic and ram pressure of the stellar wind, and the exoplanet magnetic field. If Proxima b has a magnetic field similar to that of the Earth or larger, the planet is well shielded from the stellar wind for essentially any planetary tilt, under a calm space weather. Even if Proxima b is subject to more extreme space weather conditions, e.g., a CME event, the planet is relatively well shielded by an Earth-like magnetosphere, unless the planetary tilt is larger than that of the Earth. For calm space weather conditions, the radio emission can reach 7E19 erg/s in the super-Alfvénic regime, almost an order of magnitude larger than in the sub-Alfvénic case. For extreme space weather conditions, the emission is more than two orders of magnitude larger, which yields expectations for a direct radio detection of giant planets in close-in orbits.

Theme(s): Cool Stars as Stellar Systems, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

Detecting Stellar and Substellar Companions to Low-Mass Halo Stars in Archival JWST Data

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Stellar multiplicity aids our understanding of the formation environment of a given stellar population. While binaries have been surveyed extensively in the disk-dominated Solar neighborhood, it’s difficult to establish binary fractions for the older Galactic halo stars due to their faintness/distance. As the disk and halo have distinct kinematics, metallicities, and histories, it’s reasonable to expect their binary statistics to reflect these variations in initial star-forming environment. Using Gaia, we can kinematically assemble large catalogs (~1 million) of local halo stars (within 2kpc). In a pilot study, we identified ~40 halo binary candidates amongst a subset of ~500 local halo stars serendipitously imaged by HST at sub-arcsecond

resolutions (0.1”). Our findings indicate either that halo stars have significantly lower binary fractions than disk stars, or that orbital separation distributions differ between the disk/halo populations. With over a year’s worth of archival JWST data (~1% of unique JWST images contain a local halo target), we can now extend this search for halo companions to higher angular resolution and higher contrast ratios, and potentially detect substellar companions thanks to JWST’s operation in the near/mid-infrared wavelengths (0.6-28μm). This survey will provide insight into how stellar multiplicity statistics vary throughout the Galaxy by parent population and is a technique for identifying new halo brown dwarf companions to local halo stars.

Theme(s): Cool Stars as Stellar Systems, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

The first view of the young substellar objects in the Euclid's Early Release Observations program

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Euclid space telescope has recently released its very first data to the public. Although its primary mission is to explore the distant dark Universe, its advanced visual and infrared instruments are capable of detecting faint brown dwarfs and planetary-mass objects down to an AB magnitude of 24.5 in the near infrared and 27 in the visual band. This allows it to detect T0 dwarfs at distances beyond 400 parsecs and L5 objects at distances over 600 parsecs. The mission is planned to last 5 years, covering approximately one-third of the sky, and is expected to identify over half a million substellar objects. In this poster, I will present an initial view of the substellar population in two young clusters, Sigma Orionis and Messier 78, based on Euclid's visual and near-infrared photometry from the Early Release Observations program that revealed objects of only a few Jupiter masses.

Theme(s): Cool Stars as Stellar Systems, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

A Comprehensive View of Companions to M Dwarfs: Exploring Gaia DR3 for Unseen Companions

Madison LeBlanc(1,2); Todd Henry(2); Jennifer Winters(2,3); Elliott Horch(2,4); Wei-Chun Jao(1); Aman Kar(1,2); Emily Pass(5); Eliot Vrijmoet(2,6); RECONS

Georgia State University, Atlanta, GA; RECONS Institute, Chambersburg, PA; Bridgewater State University, Bridgewater, MA; Southern Connecticut State Univ., New Haven, CT; Center for Astrophysics | Harvard & Smithsonian, Cambridge, MA; Smith College, Northampton, MA

We present a study of a volume-limited sample of ~4000 M dwarfs within 25 parsecs, dubbed the RMSTAR (RECONS M STAR) sample. The sample has been created using Gaia DR3 results, augmented with ground-based discoveries of M dwarf systems that do not appear in DR3. M dwarfs account for three of every four stars in the solar neighborhood, so it is important that we have a full understanding of their multiplicity rates. We are synthesizing various research efforts revealing stellar, brown dwarf, jovian, neptunian, and terrestrial companions to paint a rich portrait of all types of M dwarf systems. Understanding all of these populations is essential to constraining formation processes across the continuum of mass. We are surveying the RMSTAR sample using speckle imaging and radial velocity techniques to reveal companions. Here, we focus specifically on using RUWE (Renormalized Unit Weight Error), radial velocity errors, and Image Parameter Determination fraction of multiple peaks (IPDfmp) in DR3 as indicators of stellar companions to M dwarfs that are currently considered single stars. We identify additional presumed single stars that we deem likely to have stellar companions based upon examination of their RUWE, radial velocity errors, and IPDfmp. Identifying these unseen stars is the first step toward assembling the complete census of M dwarf companions from stellar masses all the way into the planetary regime.

Theme(s): New Insights into Star Formation and Evolution, Cool Stars as Stellar Systems

Identification of two new Galactic Symbiotic stars in the IGAPS footprints

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The known number of Galactic Symbiotic stars (SySts) is 275 (Akras et al. 2021) while the theoretical prediction is greater than 3000 objects (Kenyon 1986). This would imply the existence of a census problem. In order to increase the number of detected SySts in the Galaxy, we used data mining and data cross-check from IGAPS and SDSS surveys associated to varius selection criteria in the opticaland infrared. As result, 598 new candidates were found.

Theme(s): Milky Way-scale Science and Big Data, Cool Stars as Stellar Systems

Stellar Spin Down in Post-Mass Transfer Binary Systems

Meng Sun
CIERA, Northwestern University

Motivated by observations of fast-rotating accretor stars in post-mass-transfer systems, we investigated how magnetic braking affects the spin-down of individual stars during binary

evolution using the MESAbinary module. During binary evolution, mass transfer can spin up the accretor star, akin to resetting a gyro-clock, allowing us to observe how magnetic braking slows down the accretor stars. Magnetic braking involves the magnetized corona wind leaving the surface of the stars, following the open magnetic field lines, and reducing the star's angular momentum. In traditional applications of magnetic braking physics to binary evolution, it is often assumed that systems are tidally synchronized, and angular momentum is reduced directly from the orbit. However, in our simulations, we do not assume systems must be tidally locked and implement four different magnetic braking prescriptions for comparison with observations. Our major finding is that despite magnetic braking causing continuous spin-down of the accretor, when the donor begins to transfer material onto the accretor, the accretor can rapidly spin up to its critical rotation rate. Post-mass-transfer accretor stars thus serve as a valuable testbed for observing how magnetic braking prescriptions operate in spinning down stars from their critical rotation. Garraffo et al. (2018)'s magnetic braking prescription was found to better align with the rotation data of post-mass-transfer accretors.

Theme(s): New Insights into Star Formation and Evolution, Cool Stars as Stellar Systems

Using Transiting Brown Dwarfs to Distinguish the Planetary and Stellar Formation Mechanisms

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In order to study planet formation in its most massive regime, we must reframe our thinking about planets, brown dwarfs, and stars away from strict partitions in mass in favor of their formation and evolution. Brown dwarfs in particular, which range from 13 - 80 MJ, encompass the region where planet and stellar formation mechanisms likely overlap, allowing us to address the question: how massive can a planet be? The success of TESS has recently granted the ability to investigate this question from a new perspective since it has more than doubled the population of known transiting brown dwarf systems. I will present the discovery and characterization of 12 new transiting companions from TESS (TOI-2844 b, TOI-3122 b, TOI-3577 b, TOI-3755 b, TOI-4462 b, TOI-4635 b, TOI-4737 b, TOI-4759 b, TOI-5240 b, TOI-5467 b, TOI-5613 b, TOI-5882 b). We confirm 7 of these systems as transiting brown dwarfs, and the rest as very low mass stars (<120 MJ) using ground-based photometric and spectroscopic follow-up through the TESS Follow-up Observing Program (TFOP). The transiting brown dwarf population now exceeds 50 systems, a population large enough to begin performing robust statistical analyses. I will provide a first glimpse into the emerging trends from the transiting brown dwarf population, showing that the transition between planet and stellar formation may not be as clear as previously thought.

Theme(s): New Insights into Star Formation and Evolution, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

Large-Scale Coronal Magnetic Funnels and Coronal Cloud Prominences

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We describe observations and modeling of coronal cloud prominences in the solar corona with applications for the high altitude cloud prominence formations in the stellar coronal field. Observing coronal cloud prominences in similar locations but over widely separated time periods, we investigate the reasons for such multiple appearances. In particular, we focus on the large scale structures of the background magnetic field using a Potential Field Source Surface model to compute the coronal field from photospheric maps. We find that coronal cloud prominences always form after filament eruptions and coronal mass ejections (CMEs) have occurred nearby. The location of the cloud prominences coincides with a magnetic field region which appears to be open but rapidly expanding, an open field with a funnel structure. Part of the plasma from the neighboring eruptions falling back towards the sun and is captured and accumulates in these funnel regions of strong non-monotonic expansion of the open field. The plasma suspension at specific heights is coinciding with the largest gradients in the field, which naturally lead to a diamagnetic hypothesis for the force counteracting gravity. We study the evolution of the funnel-like open fields during several solar rotations and find a direct relation between funnels and the presence of coronal clouds at great heights in the solar corona. We discuss applications for the formation of cloud prominences in stellar coronae of sun-like stars.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

Correlations between laboratory molecule line lists and M-star spectra

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Molecular bands of metal oxides and hydrides dominate the optical and near-infrared spectra of M dwarfs. High-resolution spectra of these bands have immense potential for determining many properties of these stars, such as effective temperature, surface gravity, elemental abundances, radial velocity, or surface magnetic fields. Techniques are being developed to do this but remain limited by the current availability and accuracy of molecular data and spectral line lists. We report metal monohydride line lists selected from near-infrared and visible laboratory data to show that specific bands in several electronic transitions can be used to identify CrH, NiH, and FeH in M stars and to determine radial velocities from Doppler shifts. The possibility of

measuring magnetic fields is also investigated for FeH and CrH. Our line lists are available at the CDS.

Theme(s): New Insights into Star Formation and Evolution, Cool Stars as Stellar Systems

Spectroscopy of flares and superflares on AU Mic

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Flares and superflares are nowadays routinely detected from photometric space missions like Kepler and TESS. However, spectroscopic characterization of flares, especially superflares, is still quite rare. Here we report on a spectroscopic monitoring campaign targeting the young active planet host star AU Mic. We observed this M dwarf during 56 partial nights with the ESO 1.52m telescope hosted by the PLATOSpec consortium. The telescope is equipped with the Echelle spectrograph PUCHEROS+. By analyzing several prominent chromospheric spectral lines, we detect 24 flares, for which we determine their durations, peak luminosities and energies. Relationships between these flare parameters are investigated. Our data also include the partial observation of a rare extreme event which already reached superflare energies in the H\alpha line emission alone.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

Fine Structure of the Age-Chromospheric Activity Relation in Solar-Type Stars: II. H\alpha Line

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Excess chromospheric emissions within deep photospheric lines are useful proxies of stellar magnetism for FGK stars. This emission decays with stellar age and is a potential determinant of this important stellar quantity. We report H\alpha chromospheric fluxes for 511 solar-type stars in a wide interval of precisely determined masses, [Fe/H], ages and states of evolution, from high S/N, moderately high resolution spectra and absolutely calibrated in flux. The comparison of H\alpha and H+K chromospheric fluxes reveals a metallicity bias affecting H+K fluxes thereby metal-rich stars with deep line profiles mimic low chromospheric flux levels, the converse being true for metal-poor stars. This bias blurs the age-activity relation, precluding age determinations for old, inactive stars unless the relation is calibrated in mass and [Fe/H]. The H+K lines being the most widely studied tool to quantify magnetic activity in FGK, care should be exercised in its use whenever wide ranges of mass and [Fe/H] are involved. The H\alpha age-activity-mass-metallicity calibration appears to be in line with the theoretical expectation that (other parameters being equal) more massive stars possess narrower convective zones and are less active than less massive stars, while more metal-rich stars have deeper convective zones and appear more active than metal-poorer stars.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

Dynamical traceback age of the Octans young stellar association

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Octans is one of the most distant (d~150 pc) young stellar associations of the Solar neighbourhood and its age is still poorly constrained in the literature. We take advantage of the state-of-the-art astrometry delivered by the third data release of the Gaia space mission combined with radial velocity measurements obtained from high-resolution spectroscopy to compute the 3D positions and 3D spatial velocities of the stars and integrate the stellar orbits in the past. We selected a clean sample of cluster members after removing potential outliers from our initial list of candidate members and performed an extensive traceback analysis using different subsamples of stars, metrics to define the size of the association, and models for the Galactic potential. In this study we derive a dynamical age of Octans that is independent from stellar models and represents the most precise age estimate that is currently available for this young stellar association.

Theme(s): New Insights into Star Formation and Evolution, Cool Stars as Stellar Systems

Reconstructing the Evolution of HZ 9: a Post-common Envelope Binary in the Hyades Open Cluster

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HZ 9 is a post-common-envelope binary consisting of a DA white dwarf and an dM main-sequence star in the Hyades star cluster. In this work, we measured precise masses of the components of HZ 9 using new ground-based radial velocity measurements and combining those with recently developed mass-luminosity relations for M dwarfs. Using the parallax measured by ESA's Gaia Mission and infrared magnitudes from the Two Micron All Sky Survey (2MASS), we determine a precise mass of the dM component. We measured single-line radial velocities of the dM using the high-resolution infrared iSHELL spectrograph on NASA's Infrared Telescope Facility, and we measured optical double-line radial velocities of both components using the DeVeny spectrograph on the Lowell Discovery Telescope. Combining the radial velocity measurements with the measured dM mass, we measure a precise mass of the DA component. Using this measured white dwarf mass and the age of the Hyades, we reconstruct the common envelope evolution of the binary.

Theme(s): New Insights into Star Formation and Evolution, Cool Stars as Stellar Systems

Star Spots with Starry

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Star spots are patches that are dark or bright on the surface of a star. They are tightly correlated to the magnetic activity of stars. We want to study star spots to better understand where the active latitude of stars are located, which helps us understand planet habitability around low mass stars. The Starry package is a set of tools that can map the surface of stars and exoplanets using time series data, with spherical harmonics. Using this, we can determine how well Starry can produce two dimensional maps from one dimensional light curves for each rotation of AU Mic. We present a comparison of surface maps produced from Starry over each rotation and those from the package Fleck, which generates maps with individual star spots.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

Study of open cluster Cr 74

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In this work, we study an intermediate-age open cluster Collinder 74 (Cr 74) placed at a distance of over 2 kpc from the Sun ($\alpha_{2000}=05^h 48^m 40.8^s$, $\delta_{2000}=+07^{\circ} 22^{\prime} 26.4^{\prime \prime}$), in the constellation of the Orion. To study open cluster Cr 74 we have used Gaia’s Data Release-3 data. The pyUPMASK and ASteCA software were used to select probable cluster members and analyze the original data set. A total of 176 probable cluster members were selected, with a probability of more than 0.95. The cluster radius was estimated to be $6.41^{\prime}$. The proper motion of the cluster was estimated ($\mu_\alpha\cos\delta=0.758$ mas/yr, $\mu_\delta=-0.929$ mas/yr). The distance modulus and age estimates were $(m-M)_0=12.04\pm0.1$ and $\log(age)=9.256\pm0.063$, respectively.

Theme(s): Milky Way-scale Science and Big Data, Cool Stars as Stellar Systems

Effects of turbulent energy cascade on the circumstellar disc

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We investigate the characteristics of circumstellar discs (CDs) produced in hydrodynamical simulations of gravoturbulent core collapse considering Kolmogorov and Burger-type turbulence. Massive discs are found to be more prevalent in the Kolmogorov regime compared to Burger-type turbulence. A significant number of discs are reported to have a radius of approximately 15 astronomical units (au) in both turbulence regimes. Extended discs with radii larger than 15 au are more common in the Kolmogorov turbulence scenario. In general, both turbulence regimes yield disc radii in the ranges of 7 au to 30 au (for Kolmogorov) and 13 au to 39 au (for Burger-type). The corresponding ranges of disc masses are reported to be between 30.37 Jupiter masses ($M_{\rm Jup}$) and 0.92 solar masses ($M_{\odot}$) for Kolmogorov turbulence and 2.09 $M_{\rm Jup}$ to 0.13 $M_{\odot}$ for Burger-type turbulence. The ratio $M_{\rm disc}/M_{\rm star}$ is higher in models of Kolmogorov-type turbulence compared to Burger-type turbulence. No correlation is found between disc radius ($R_{\rm disc}$) and disc mass ($M_{\rm disc}$) over the explored range of initial temperatures (8 K, 10 K, 12 K, and 14 K) and turbulence types. Both subsonic and supersonic velocity dispersions cause variations in the specific angular momentum of infalling gas, particularly for discs with radii around 16 au to 21 au. The radial profiles of circumstellar discs do not show correlation with the initial conditions.

Theme(s): New Insights into Star Formation and Evolution, The Sun and Cool Stars in the Time Domain

Recipe for an Equation of State for the Entire Structure of Stars

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A quality equation of state (EOS) is crucial for the hydrostatic support of our stellar models, crucial for interior opacities and spectral synthesis, as well as for accurate sounds speeds for helio- and asteroseismology. We present here some of the most important ingredients in our recipe (T-MHD) for a high quality equation of state for stellar plasmas in LTE, building on the ground breaking work of the Mihalas-Hummer-Däppen (MHD) EOS of the late 80'ies. The new ingredients include 100s of molecules subject to pressure dissociation, more elements, realistic microfield distribution functions (for pressure ionization), full extent of Coulomb and exchange effects, extensive atomic/ionic energy level tables edited for consistency and completeness, etc., etc. We show the effects on the EOS of some of those upgrades which are particularly relevant for cool stars.

Theme(s): New Insights into Star Formation and Evolution, Cool Stars as Stellar Systems

Spectroscopic follow up of the Gaia ultracool dwarf sample

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The Gaia 3rd data release allowed the identification of over 90 thousand candidate ultracool dwarfs, objects with spectral types later than M7 and estimated effective temperatures of less than 2700K. These objects are a mix of young planetary mass objects, brown dwarfs and the lowest mass hydrogen-fusing stars. They cover the stellar - sub-stellar boundary, objects with differing dominant formation mechanisms and with varied atmospheric physics. To complement the Gaia photometric and astrometric information this team has been carrying out spectroscopic follow up with a priority to complete the census of ultracool dwarfs within 30pc, any new L dwarf candidates and objects in potential benchmark systems. In this poster we summerise the current observational dataset and the intentions for the future.

Theme(s): Milky Way-scale Science and Big Data, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

A study of near-ultraviolet and optical properties of M dwarf flares

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University of America; U.S. Naval Research Laboratory; Southeastern Universities Research Association (SURA)

Near-ultraviolet (NUV) stellar flares can drive photochemistry in the atmospheres of and harm any surface life on the exoplanets they host. We analyzed an extensive dataset of NUV and optical flares from young and old M dwarfs observed simultaneously with the Transiting Exoplanet Survey Satellite (TESS) and the Neil Gehrels Swift Observatory with supporting data from K2 and the Hubble Space Telescope. In total, we observed 213 NUV flares from 24 nearby M dwarfs, with \sim27 percent of them having detected optical counterparts, and found that all optical flares had NUV counterparts. We explore the energy fractionation of flares between the two bandpasses and find a slight decrease in the optical/NUV ratio with increasing NUV energy, a trend in agreement with prior investigations on more energetic G-K stellar flares. We present an empirical relationship between NUV and optical flare energies and compare to predictions from radiative-hydrodynamic and blackbody models. We find that within error bars, the flare frequency distributions (FFDs) of both NUV and optical flares across all M dwarf subtypes exhibit comparable slopes.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

UCD flares: similar characteristics to FGKM flares but cannot drive abiogenesis

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In this contribution, we present the characterization of the photometric variability of 208 ultra-cool dwarfs (UCDs) with spectral types between M4 and L4 using 2-min cadence data from the space mission TESS. We determined the rotation period of 87 UCDs and detected 778 flares in 103 of them. Through the analysis of these data, we were able to conclude that the correlations among the measured flare characteristics, namely the slope of the cumulative flare frequency distribution, flare amplitude, duration and energy, are consistent with those measured for dwarf stars of earlier spectral types. Our results indicate that UCD flares are similar to those produced by FGK and earlier M dwarfs. According to traditional understanding, magnetic fields in stars with convective envelopes are seated at the tachocline, which fully-convective UCDs do not have. In this context, our results suggest that the physical mechanism that produces flares might be similar in these very differently structured dwarfs, for example if driven by magneto-instabilities near their surfaces. Flares are thought to initiate abiogenesis in terrestrial planets; we find that the UV energy emitted during the UCD flares in our sample is not enough to drive prebiotic chemistry on any terrestrial planet potentially orbiting them.

Theme(s): The Sun and Cool Stars in the Time Domain, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

The Kraft Break Sharply Divides Low Mass and Intermediate Mass Stars

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Main sequence stars transition at mid-F spectral types from being slowly rotating (cooler stars) to being rapidly rotating (hotter stars), a transition known as the Kraft Break and attributed the disappearance of the outer convective zone, causing magnetic braking to become ineffective. To investigate the location and width of this Break more precisely, we assembled spectroscopic measurements of 405 F stars within 33.33 pc of the Sun. Once young, evolved and candidate binary stars are removed, the distribution of projected rotational velocities shows the Break to be well-defined and sharp. Nearly all stars redder than $G_{BP}-G_{RP} = 0.60$ mag are slowly rotating ($v\sin i \lesssim 20$ km/s), while only 4 of 40 stars bluer than $G_{BP}-G_{RP} = 0.54$ mag are slowly rotating, consistent with that expected for a random distribution of inclinations. The Break is centered at an effective temperature of 6550 K and has a width of 200 K, corresponding to a mass range of 1.32 to 1.41 $M_\odot$. The Break, as defined above, is nearly but not fully established in the 650 Myr Hyades cluster; we speculate that it should be established in populations older than 1 Gyr. Finally, we propose that the Kraft Break provides a less ambiguous and more useful division, for both professional and pedagogical purposes, between what are called low mass stars and intermediate mass stars; the Kraft Break is observationally well-defined and is physically linked to a change in stellar structure.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

Investigating Nearby Young Moving Group Membership with Gaia DR3 and Virtual Reality

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Nearby young moving groups (NYMGs) are comoving, loosely bound associations of young stars (<150 Myr) within ~120 pc of the sun. Due to their youth and proximity, NYMG members provide prime candidates for the direct imaging of exoplanets, the study of late-stage circumstellar disks, and general pre-main sequence stellar evolution. To refine and enhance the membership of known NYMGs, we are analyzing the spatio-kinematic and photometric data from Gaia Data Release 3 (DR3) with a virtual reality tool, StarGateVR. StarGateVR is purpose-built to analyze and filter the inherently multidimensional Gaia data. We report the recovery of ~1000 members and, potentially, new candidates of eight known NYMGs with this StarGateVR-based approach. As a case in point, we describe the recovery of a disk-bearing star previously assigned to the ~50 Myr-old Argus Association as a member of the ~20 Myr-old

beta Pictoris Moving Group (bPMG), which is more congruent with the status of the star as actively accreting from its circumstellar disk. This revised membership status is more congruent with the status of the star as actively accreting from a circumstellar disk. These initial tests of StarGateVR establish its potential application to the task of exploring Gaia DR3 data to distinguish low mass, cool members of NYMGs from the field population. This research is supported by NASA Astrophysics Data Analysis Program grant 80NSSC22K0625 to RIT.

Theme(s): Milky Way-scale Science and Big Data, Cool Stars as Stellar Systems

Near-Infrared Spectroscopy of the Sun and Solar Analog Star HD 76151

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Precise information on a stars surface gravity (log g), metallicity ([Fe/H]), effective temperature (Teff), and stellar atmospheric parameters is necessary to determine the physical structure of the star. In this study, we assessed the impact of the NIR wavelength range on stellar parameter calculations by creating a new line list for iron and α elements in the near-infrared (NIR) region. The line list encompasses the Y, J, H, and K bands or 1 μm to 2.5 μm, as its spectral range. The high-resolution ESO NIR spectrum of the Sun was produced by the NSO/Kitt Peak FTS and used to check atomic data quality. We also performed LTE analysis of high-resolution echelle infrared spectra of a solar analog star, HD76151. The H- and K-band spectra of the star were obtained using the IGRINS spectrograph and the 2.7 m Harlan J. Smith Telescope (HJST). As an additional test, we used the Line Depth Ratio method in the H- and K-band spectra of the star to calculate the atmospheric parameters for the final model. The impact of neutral and ionized iron lines on stellar atmospheric parameters was investigated. Within this framework, we also performed high-resolution optical spectroscopy of the optical KPNO spectrum of the Sun and HARPS spectrum of HD76151 for comparison.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

The plage time series from various viewing angles : impact on temporal modulation detection

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The Ca II K and H lines are used to monitor a large number of stars, including the Sun. The viewing angle under which the star is observed impacts the visibility of magnetic structures and hence the integrated flux measured. We have modelled the impact of the inclination angle on Ca II K plages time series on the detection of short and long-term modulations. For this, we have reconstructed the solar disk under different viewing angles from full-disk images recorded at the Royal Observatory of Belgium with the USET telescope between 2012 and 2024. We will discuss our work and its implication for monitoring Sun-like-stars.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

The Influence of Coronal Mass Ejections on hot Jupiters' Atmospheres

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Space weather holds fundamental importance and is increasingly central in the study of exoplanets. Throughout their entire lifespan, planets are enveloped by the stellar wind, exposing them to an extreme environment. It is well-established that all stars possess a stellar wind, subject to temporal variations. In the case of our solar system, the most important disturbances in the solar wind are known as coronal mass ejections (CMEs). These CMEs involve massive ejections of plasma, with a total mass approximately on the order of 10^{15} g, traveling at velocities around 500 km/s. Recent observations indicate that for stars that are not the Sun, these CMEs could be even more extreme (Argiroffi et al., 2019). In my presentation, I will show the results derived from our three-dimensional Magnetohydrodynamic (MHD) modeling of a stellar CME colliding with the upper atmosphere of a hot Jupiter. Our investigation determines how the CMEs affect the planetary mass loss rate encompassing diverse scenarios involving various CME characteristics, with a particular focus on examining the impact of the planetary magnetic field in shielding the planetary atmosphere.

Theme(s): New Insights into Star Formation and Evolution, Cool Stars as Stellar Systems

Observing starspot umbrae and penumbrae using exoplanet transit photometry

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While current methodologies map large-scale starspots on rapidly rotating active stars, investigation of active regions structure on slowly rotating, solar-like stars is challenging. For this, we introduce a novel analysis technique aimed at extracting the umbral and penumbral structure of starspots from exoplanet transit light curves. Our goal is to determine the constraints associated with penumbra detectability. Our method uses simulated transits of a solar active region to determine the resulting flux ratios of occulted umbra and penumbra. The detection of starspot penumbrae depends on their flux variations in transit light curves surpassing the photometric noise. This detection threshold is related to the apparent stellar magnitude, as noise predominates for all but the brightest stars. Thus a large transit depth is crucial for detection, albeit the penumbra potentially becoming undetectable due to low contrast relative to the photosphere in the case of the coolest stars. For systems featuring a 2 or 3 R_{\earth} planet transiting an M or small K dwarf star, low-contrast (high-intensity) penumbrae may be discernible for stars with M_v \leq 13. This shows the feasibility of detecting stellar umbrae and

penumbrae with flux ratios similar to solar values (1.7 - 4.4). Consequently, we demonstrate that future space-based transit photometry may provide characterization of stellar spot structures, thereby enhancing our understanding of stellar activity and dynamos.

Theme(s): Cool Stars as Stellar Systems

Benchmark handbook of ultracool dwarf stars in multiple systems

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The work consists in “developing a handbook of ultracool dwarf stars in multiple systems”, using Gaia data. It is achieved with a software written in Python, which can generate and update the handbook automatically when new data is provided. The program divides stars in the same system, generating for each system an HR diagram and a sky image (using 2MASS) with the target stars, along with the astrophysics info requested initially. Then it generates the LaTeX code containing all the requested data, compiling it into a single file (or in multiple files, divided by RA, as the user wants). The final handbook can also be expanded manually by adding single latex files containing info about the stars or the entire system, which will be included in the next script runs.

Theme(s): Cool Stars as Stellar Systems, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

Redshifting the Study of Cold Brown Dwarfs and Exoplanets: the 10–15um Region as a Mass Indicator

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JWST is opening many avenues for research and exploration. For cold brown dwarfs and exoplanets, JWST has opened the door to the mid-infrared wavelength region, where such objects emit significant energy. For the first time, astronomers have access to mid-infrared spectroscopy for objects colder than 600 K. The first spectra appear to validate the model suite known as ATMO2020++: atmospheres which include disequilibrium chemistry and have a non-adiabatic pressure-temperature relationship. Preliminary fits to MIRI spectroscopy of Y dwarfs show that the slope of the energy distribution from lambda ~5 um to lambda ~10 um is very sensitive to gravity. We explore this phenomenon using PH3-free ATMO2020++ models and updated WISE W2 - W3 colors. We find that an absolute 5 um flux measurement constrains temperature, and the ratio of the 5 um flux to the 10 – 15 um flux is sensitive to gravity and insensitive to metallicity. With gravity and temperature constrained, evolutionary models provide mass and age estimates for these bodies. For brown dwarfs and exoplanets cooler than 600 K, MIRI spectroscopy or imaging can constrain Teff to ~20 K and log g to ~0.25 dex. These constraints would determine whether an isolated 400 K object is a 0.8 Gyr-old 7 Jupiter-mass

body or a 3 Gyr-old 12 Jupiter-mass body, for example. Hence key diagnostics for cold worlds can be measured by moving from the near-infrared regime to the mid-infrared.

Theme(s): New Insights into Star Formation and Evolution, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

Exposing the Lyman-alpha Profiles of Low-Mass Stars

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Lyman-alpha (Ly-a) emission at 1216 A is the dominant radiation source for low mass stars at FUV wavelengths. It is critical for informing stellar atmosphere models used to predict the EUV spectrum, but directly measuring a low-mass star's Ly-a emission is almost always impossible because of the contaminating effects of interstellar hydrogen. Stars with very large radial velocities (>100 km/s) have their Ly-a emission Doppler shifted away from contaminating sources, allowing for the rare opportunity to measure intrinsic Ly-a emission. We have used HST/STIS to observe a unique sample of six low mass stars for which complete and accurate measurement of their Ly-a line profile is possible due to their very large radial velocities. Our sample uniformly covers the critical K to M effective temperature range, and results show complete line profiles with the depth of the self-reversed cores steadily increasing with increasing effective temperature. We have used the PHOENIX atmosphere code to compute models of each star and have found that the K stars are all best matched by nearly the same chromospheric structure. To match the depth of the self-reversal, we adjust the microphysics at the boundary of the chromosphere and transition region. Here we present how these complete and resolved Ly-a profiles have improved constraints on the shape of the upper atmosphere temperature structure of K and M stars, which is the primary formation region for light emitted the EUV-NUV spectral range.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

A Survey of Model Fits to Archival L- and T-Type NIR Spectra

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Theoretical atmosphere models based on known physics and chemistry can be used as tools to interpret and understand our observations of brown dwarfs. We have fit archival near-infrared spectra of over 300 brown dwarfs with atmosphere models from the Sonora and Phoenix groups. Using the parameters of the best-fit models as estimates for the physical properties of the brown dwarfs in our sample, we have performed a survey of how brown dwarf atmospheres evolve with spectral type and temperature. In this poster, we present some of the fit results and

observed trends. We also categorize objects with the same "deviant" spectral features into families and discuss possible causes for their unique spectral traits.

Theme(s): Cool Stars as Stellar Systems, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

Spatially Dependent Photometric Activity of FGKM dwarfs

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We study the relationship between Galactic location (R, Z) and photometric activity for a few million FGKM dwarf stars. For this purpose, we identify several unique flare events as a proxy for magnetic activity from the SkyMapper Data Release 4. We adopt vertical distance |Z| from the Galactic disc as a proxy for age and confirm a strong trend of flaring fraction decreasing with growing stellar age. We will discuss further on how the flaring activity varied as a function of (R, Z, spectral type).

Theme(s): Milky Way-scale Science and Big Data, The Sun and Cool Stars in the Time Domain

The first uniform analysis of transiting brown dwarf host star ages

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This work explores the discrepancies between the transiting brown dwarf (BD) population and substellar age-radius relationships by 1) performing a homogeneous analysis of the ages of BD host stars with the MIST models, and 2) examining radius inflation mechanisms in BDs and giant planets and comparing the effects of these as a function of mass. For the first time, this work allows us to be able to compare the relative ages of transiting BD host stars for all 47 known transiting BDs. This work also takes a more critical look at the likely causes of radius inflation in transiting BDs as a function of mass. Both low-mass (13-25M_J) and high-mass (70-75M_J) brown dwarfs show clear signs of radius inflation at ages beyond 1 Gyr, but it is unclear whether or not the inflation mechanisms are shared between low- and high-mass brown dwarfs. This study shows that for most BDs above 25M_J, incident flux may be negligible as a primary factor in radius inflation, which highlights the mass dependence of this phenomenon and distinguishes it from incident flux radius inflation seen in the giant planet population.

Theme(s): Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

Long-term near-infrared monitoring of young stellar objects across the hydrogen burning limit

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Near-infrared variability monitoring of the youngest low-mass stars and substellar objects can reveal much valuable information, including the dynamics of inner protoplanetary disks, angular momentum evolution, magnetic processes, and other information. We present results from JHK multi-wavelength UKIRT monitoring of two star-forming regions in Perseus targeting over 500 very low mass YSOs and substellar objects with known spectral type (ranging from M0 – L3, i.e., ~0.3 – 0.01 Msun). Our data include continuous (~nightly) monitoring for over eight months. This allows us to carefully trace variability (including variability arising from magnetic processes) across a wide mass range that straddles the hydrogen burning limit.

Theme(s): The Sun and Cool Stars in the Time Domain, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

Cool Stars, Hot Tech: Spectral Typing of M, L, and T Dwarfs with AI

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Low-mass stars and brown dwarfs span the spectral type range of M, L, T, and Y, with an effective temperature \lesssim 3800K. Currently, the classification of these ‘Cool Stars’ relies heavily on visual inspection, spectral features, or spectral indices. However, the increasing volume of data from new sky surveys necessitates a more efficient spectral typing approach. In this project, we investigate a machine-learning model capable of classifying spectra from M0 to T9 dwarfs, identifying metallicities classes (e.g., sd, esd), and surface gravity classes (e.g., \beta, \gamma). The model is trained using synthetic spectra generated from 70 spectral standards and tested on \sim 2000 low-resolution (R \sim 120) near-infrared (NIR) spectra in the SpeX Prism Library (SPL), one of the largest brown dwarf archives worldwide. We evaluated the performance of three machine-learning classifiers: Random Forest (RF), K-Nearest Neighbors (KNN), and Support Vector Machines (SVM). The KNN performs the best, achieving an accuracy of 88.49\% within \pm1 SpT. We also investigated the impacts of two different normalization methods described by \citet{2006ApJ...637.1067B} and \citet{2018AJ....155...34C} on the classification process. This study demonstrates a promising approach to classifying low-temperature dwarfs, addressing the challenges of limited data, and highlighting the importance of various spectral regions in determining surface gravity and stellar age.

Theme(s): Milky Way-scale Science and Big Data, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

Direct Imaging Discovery of a Substellar Companion to the Accelerating Variable Star, HIP 39017

Taylor L. Tobin (1,2); Thayne Currie (3,4); Yiting Li (1,5); Jeffrey Chilcote (2); Timothy D. Brandt (5); Brianna Lacy (6); Masayuki Kuzuhara (7,8); Maria Vincent (9); Mona El Morsy (4); Vincent Deo (3); Jonathan P. Williams (9); Olivier Guyon (3); Julien Lozi (3); Sebastien Vievard (3); Nour Skaf (6); Kyohoon Ahn (3); Tyler Groff (10); N. Jeremy Kasdin (11); Taichi Uyama (12); Motohide Tamura (7,8,13)
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Direct imaging of brown dwarfs and and young, self-luminous Jovian companions to nearby stars is uniquely poised to probe models of planet formation. However, large scale, unbiased surveys have found that substellar companions that can be imaged with modern, ground-based systems are rare. To account for this shortcoming, recent direct imaging surveys have turned toward targeted searches, focusing on stars showing dynamical evidence for a companion through, for example, astrometric acceleration. We present the direct imaging discovery of a substellar companion (massive planet or low-mass brown dwarf) towards one such astrometrically accelerating star: the young \gamma Doradus-type variable, HIP 39017 (HD 65526). The companion's SCExAO/CHARIS JHK (1.1-2.4 \mum) spectrum and Keck/NIRC2 L' photometry indicate that it is an L/T transition object, with a comparison to several atmospheric model grids yielding a significantly better fit to cloudy models than cloudless models. We discuss current dynamical mass constraints and spectral analysis. This discovery further reinforces the improved efficiency of targeted direct imaging campaigns informed by long-baseline, precision stellar astrometry. Between the system's youth and potential for independent dynamical mass constraints and asteroseismic age modeling of its primary, HIP 39017b provides a new testing ground for substellar evolutionary and atmospheric models.

Theme(s): Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

Probing the Atmosphere of the Sun-as-a-Star using Seismic Waves

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At the turn of the 21st century, helioseismology was extended to other stars as asteroseismology, emerging as a powerful tool to study the physical processes in stellar interiors. This field gained further momentum with the advent of space missions such as CoRoT and Kepler. These missions have enabled us to probe internal properties of stars, such as density, composition, rotation, and convective mixing, which are challenging to acquire using spectroscopy and photometry. However, while current asteroseismic analyses provide insights into stellar interiors, the atmospheres of stars have remained largely unexplored. Here we present a groundbreaking approach to probe stellar atmospheres. By analyzing Doppler velocity data from two spectral lines with different formation heights in the atmosphere, we can model the propagation of acoustic waves between these heights. This method, extensively utilized on the Sun's surface to estimate atmospheric properties, is adapted here to simulate solar data as if it were from a distant star. Our analysis sets the stage for seismic probing of stellar atmospheres beyond the Sun. Preliminary results reveal promising avenues for studying the sound speed (temperature), radiative cooling times (energy transport), and magnetic cycles (stellar dynamos), all of which are crucial for stellar modeling efforts. This research opens new doors for probing stellar atmospheres in ways never before possible.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

MML 48: a new pre-main sequence eclipsing binary with the primary at the onset of the CNO cycle

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We present the discovery and initial characterization of the eclipsing binary (EB) MML 48 which is part of Upper Centaurus Lupus and has an estimated age of 16 Myr. Both components in the system are pre-main sequence (pms) stars, making this system one of four known pms EBs with stars of intermediate ages (16-17 Myr). We used WASP and TESS data to refine the orbital period to ~2.017 d. By fitting the single-lined radial velocity curve from CHIRON, FEROS and SOAR data and the multi-band light curves from 0.9m SMARTS and FTS showing both eclipses, we are able to measure the fundamental properties of the two eclipsing stars. The difference in mass between the MML 48 stars is the largest in the known sample of pms EBs, with a primary mass of 1.2 \pm 0.07 M_\odot and a secondary mass of 0.2509 \pm 0.0078 M_\odot. Their radii are inflated as expected for pms stars, 1.574 \pm 0.026 R_\odot and 0.5871 \pm 0.0095 R_\odot. The mass-radius diagram of the eight 16-17 Myr eclipsing stars compared to evolutionary models show that the MML 48 primary is likely at the onset of the CNO cycle before achieving thermal equilibrium.

Theme(s): The Sun and Cool Stars in the Time Domain, Cool Stars as Stellar Systems

Direct Imaging Discovery of HD 63754 B, a ~20 au Massive Companion Near the Hydrogen Burning Limit

Yiting Li, Timothy D. Brandt, Qier An, Kyle Franson, Taylor Tobin, Thayne Currie, Minghan Chen, Lanxuan Wang, Trent J. Dupuy, Rachel Bowens-Rubin, Maïssa Salama, Briley L. Lewis, Aidan Gibbs, Brendan P. Bowler, Rebecca Jensen-Clem, Jacqueline Faherty, Michael P. Fitzgerald, Benjamin A. Mazin
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We present the joint astrometric and direct imaging discovery, mass measurement, and orbital analysis of HD 63754 B, a companion near the stellar-substellar boundary orbiting ~20 AU from its Sun-like host. HD 63754 B was observed in our ongoing high-contrast imaging survey targeting stars with significant proper-motion accelerations between Hipparcos and Gaia consistent with wide-separation substellar companions. We utilized archival HIRES and HARPS radial velocity data, together with the host star's astrometric acceleration extracted from the Hipparcos-Gaia Catalog of Accelerations (HGCA). We subsequently imaged HD 63754 B at its predicted location using the Near Infrared Camera 2 (NIRC2) in the L' band at the Keck Observatory. We then jointly modeled the orbit of HD 63754 B with RVs, Hipparcos-Gaia accelerations, and our new relative astrometry. For HD 63754 B, we infer a bolometric luminosity of log(L_{bol}/L_{sun})= -4.55 \pm0.08 dex using a comparison sample of L and T dwarfs with measured luminosities. Although uncertainties linger in age and dynamical mass estimates, our analysis points toward HD 63754 B's identity as a brown dwarf on the L/T transition rather than a low-mass star, indicated by its inferred bolometric luminosity and model-estimated effective temperature. Future RV, spectroscopic, and astrometric data such as those from JWST and Gaia DR4 will clarify HD 63754 B's mass, and enable spectral typing and atmospheric characterization.

Theme(s): Cool Stars as Stellar Systems, Brown Dwarfs and Giant Exoplanets: Future Prospects and Thirty Years of Discovery

Observations of a Failed Solar Filament Eruption Involving External Reconnection

Yuehong Chen

The PEPSI ultra-high resolution spectral library of M dwarfs

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We present a forthcoming library of M dwarf spectra taken with the ultra-high resolution spectrograph PEPSI (R = 250 000). Our library consists of 7 nearby inactive M dwarfs spanning spectral types M0 to M7, including known planet hosts GJ581 (M3), Barnard’s Star (M4), and Teegarden’s Star (M7). Intended applications include radial velocity templates for exoplanet searches as well as calibration of stellar atmosphere models. The wavelength coverage (383 — 906 nm) approximately captures the peak of the SED for M dwarfs, representing a sweet spot for their characterisation. In particular, the 700 — 900 nm window is rich in spectroscopic information, with many segments relatively clean from molecular contamination, offering an ideal laboratory for chemical abundance measurements. We show examples of exquisitely resolved atomic and molecular features and compare them with models. While some features, like the hyperfine structure of vanadium, are remarkably well-described by synthetic spectra, others show severe mismatches with state-of-the-art models, highlighting their limitations. The PEPSI spectral templates will be an invaluable resource for the community by enabling precise radial velocity measurements, as well as detailed tests of cool dwarf atmosphere models and refinements of relevant line lists for chemical analysis.

Theme(s): Milky Way-scale Science and Big Data, Cool Stars as Stellar Systems

A Statistical Study of Soft X-ray Flares on Solar-type Stars

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