Poster Abstracts for

Exoplanets, the Solar System and the Origins of Stars, Planets and Life

Parallel Session

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Topic: Exoplanets, the Solar System and the origins of Stars, Planets and Life

OCMAP: Open Cluster Membership Analysis Program

Open clusters are groups of gravitationally bound stars formed from the same molecular gas cloud. These clusters and their stellar metallicity enhance our knowledge of stellar evolution, stellar cluster characteristics, and the chemical evolution of the Milky Way (MW) Galactic disk. Stars that are actual members of the cluster must be identified within each cluster's observed field of view. We present OCMAP, an open-source customizable membership analysis program developed in python for use within the astronomy data science community. Cluster membership is determined using simulated star fields and stellar photometry magnitudes across multiple filters. OCMAP matches stars across images, plots color-magnitude diagrams (CMDs), standardizes stellar magnitudes, and calculates the local and field star density on a CMD for each prospective member in order to determine a probability of membership for each star. OCMAP was developed to ultimately determine the membership and metallicity of 42 open clusters observed with the Apache Point Observatory 3.5m telescope and Dominion Astrophysical Observatory 1.83m Plaskett telescope using Sloan and Strömgren filters, respectively. We tested OCMAP on 8 of the 42 open clusters we have observed, and now present the resulting members-only Sloan [u-g] vs. [g-r] and Strömgren [m1] vs. [b-y] metallicity plots, as well as Sloan [g] vs. [g-r] and Strömgren [y] vs. [b-y] color-magnitude diagrams for each open cluster.

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Yaroslav Pavlyuchenkov (Institute of Astronomy, Russian Academy of Sciences)
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Topic: Exoplanets, the Solar System and the origins of Stars, Planets and Life

The Eccentric Cavity, Triple Rings, Two-Armed Spirals, and Double Clumps of the MWC 758 Disk

Spatially resolved structures in protoplanetary disks hint at unseen planets. Previous imaging observations of the transitional disk around MWC 758 revealed an inner cavity, a ring-like outer disk, emission clumps, and spiral arms, all possibly generated by companions. We present ALMA dust continuum observations of MWC 758 at 0.87 millimeter (mm) wavelength with 43×39 mas angular resolution (6.9×6.2 AU) and 20 μJy beam−1 rms. The central sub-mm emission cavity is revealed to be eccentric; once deprojected, its outer edge can be well- fitted by an ellipse with an eccentricity of 0.1 and one focus on the star. The broad ring-like outer disk is resolved into three narrow rings with two gaps in between. The outer two rings tentatively show the same eccentricity and orientation as the innermost ring bounding the inner cavity. The two previously known dust emission clumps are resolved in both the radial and azimuthal directions, with radial widths equal to ∼4× the local scale height. Only one of the two spiral arms previously imaged in near-infrared (NIR) scattered light is revealed in ALMA dust emission, at a slightly larger stellocentric distance owing to projection effects. We also submit evidence of disk truncation at ∼100 AU based on comparing NIR imaging observations with models. The spirals, the north clump, and the truncated disk edge are all broadly consistent with the presence of one companion exterior to the spirals at roughly 100 AU.

Zack Draper (University of Victoria)

Topic: Exoplanets, the Solar System and the origins of Stars, Planets and Life

The Symbiosis Between ngVLA and High-Contrast Imaging for Debris Disks

Recent surveys from high-contrast imaging instruments such as the GPI and SPHERE have been able to directly resolve exoplanetary systems. Numerous debris disks have been resolved at high resolution such that structure and asymmetries can be seen. This is allowing for detailed modeling in the near-IR of the dust grain properties from their minimum grain size, size distribution, porosity and even looking for ice features in their spectrum. However, long wavelength observations offer a unique diagnostics for the dust mass that scattered light observations are insensitive too. The angular resolution between 8-meter class telescopes in the near-IR is equivalent to radio wavelengths at km baselines, allowing for a unique symbiosis with near-IR high contrast imaging. I will discuss recent results from an interesting debris disk resolved by GPI, HD 111520, which highlights the usefulness of having contemporaneous long wavelength imaging of the disk from a facility such as the ngVLA.

Laura Fissel (NRAO)

Topic: Exoplanets, the Solar System and the origins of Stars, Planets and Life

Studying Star Formation with the Probe of Inflation and Cosmic Origins (PICO)

The Probe of Inflation and Cosmic Origins (PICO) is a concept for a probe-class NASA mission. PICO will provide an all-sky map of the polarized emission from the Galaxy with an unprecedented combination of sensitivity and angular resolution in 21 frequency bands covering 21-799 GHz. With 1.1 arcmin FWHM resolution at 799 GHz, PICO will make detailed maps of thousands of molecular clouds, and will significantly advance our understanding of the role of magnetic fields in the star formation process. In addition, high-resolution observations of magnetic fields in the diffuse ISM will be used to study feedback processes and energy transport in the Milky Way.

Logan Francis (University of Victoria)

Doug Johnstone (NRC/HAARC)

Topic: Exoplanets, the Solar System and the origins of Stars, Planets and Life

Probing Episodic Accretion during the Earliest Stages of Star Formation with ALMA

Variability of pre-main-sequence stars observed at optical wavelengths has been attributed to fluctuations in the mass accretion rate from the circumstellar disk onto the forming star. Detailed models of accretion disks suggest that protostars in the earliest stages of their formation should also exhibit variations in their accretion rates, but these objects are hidden from observation in the optical and near-IR by their thick natal envelopes of gas and dust. Fortunately, changes in the brightness of the envelope dust at mid-IR to mm wavelengths may be tracked as a proxy for the accretion luminosity. The ongoing JCMT Transient survey is conducting monthly sub-mm monitoring of star forming regions to investigate this, and has found 10% of protostars show secular variations in brightness at about 5%/yr. The JCMT is a single dish telescope however, and can not probe the smallest scales within protostellar envelopes where variability should be strongest. Interferometers such as ALMA offer the resolution and sensitivity to observe small fluctuations at these spatial scales. There are however, many complications for comparing different epochs of interferometer observations. We have developed novel methods for calibrating interferometric data, and applied them to CARMA and ALMA observations separated by a period of eight years for four protostars in Serpens. While we find no brightness variation above a factor of ~2, we cannot test lower levels of variability due to the limited sensitivity of the CARMA observations. We plan future ALMA observations using a well defined and controlled observing strategy to provide robust constraints on models of accretion in the youngest protostars.

Tyler Gordon (The University of Washington)

Eric Agol (The University of Washington)

Topic: Exoplanets, the Solar System and the origins of Stars, Planets and Life

Modeling Stellar Micro-variability in Multiwavelength Observations: Applications to Exomoon Detection

In the era of the James Webb Space Telescope, the primary barrier to detecting shallow exoplanet transit signatures will be the presence of correlated stellar noise. Correlated noise from stellar granulation can mimic and obscure transits. Current methods for mitigating these effects cannot reliably distinguish between transits and variability features. This is especially problematic for attempts at detecting exomoons because of their predicted shallow transit depths. We propose to extend gaussian process-based correlated noise models to enable simultaneous modeling of light curves in multiple wavelength bands. Because stellar variability exhibits different wavelength dependence than transits, our model will be able to distinguish between the two effects. We propose to use our method to analyze transit observations made with JWST's NIR- Spec PRISM in order to search for transiting exomoons with greater sensitivity than currently achievable. Observations of exomoons have the potential to offer insight into the formation and habitability of exoplanetary systems.

Claire Marie Guimond (McGill University)

LUVOIR Mission Concept Team

Topic: Exoplanets, the Solar System and the origins of Stars, Planets and Life

Probing Exoplanets and the Solar System with the Large UV/Optical/IR Surveyor

The LUVOIR mission concept is a space observatory for the 21st century. Its very large aperture (8–15 m) and broad wavelength range (far-UV to near-IR) mean that LUVOIR will break ground across a broad range of astronomy, probing stars, galaxies, and cosmology. In particular, LUVOIR will enable unique science on exoplanets and the solar system with its suite of imagers and spectrographs. Equipped with an ultra-high-contrast coronagraph, ECLIPS, LUVOIR will detect hundreds of planets orbiting nearby stars, including dozens in the habitable zones of Sun-like stars, constraining occurrence rates and hence planet formation/migration scenarios. Moreover, LUVOIR will spectrally characterize these planets to determine the nature of their atmospheres and surface. Key biogenic and climatically-active gases have multiple absorption bands in the ECLIPS range (0.2 μm to 2.5 μm); we could constrain their abundances or falsify prior detections. LUVOIR's large aperture will further enable surface mapping and rotation period recovery of small and large planets, further constraining theories of planet formation, as well as providing additional insight into the atmospheric dynamics of these worlds. In addition to revolutionizing our view of Earth analogs via direct imaging, LUVOIR will be a powerful tool to study the atmospheres of short-period planets via transit spectroscopy, and, for the hottest planets, eclipse and phase observations. Finally, UV observations of planets and disks with the LUMOS spectrographic imager and the POLLUX spectropolarimeter will aid new science on star/planet interactions, planetary magnetospheres, and protoplanetary disk properties, addressing longstanding questions on planet formation. As for our solar system, LUVOIR will image cryptic bodies in flyby quality with the HDI instrument, revealing Pluto's surface geology and Europa's oceanic jets, for example. The scale of the LUVOIR mission concept is so ambitious that many of its science questions are still to be discovered.

Elizabeth Gutierrez (The University of Texas - Austin)

Cara Battersby (University of Connecticut)
Meredith MacGregor (Carnegie Department of Terrestrial Magnetism)

Topic: Exoplanets, the Solar System and the origins of Stars, Planets and Life

Radio Interferometry with the SMA: Uncovering Hidden Star Formation in Our Extreme Galactic Center

Radio interferometry provides the best tool to identify embedded star-forming cores in cold, dense, molecular clouds of gas and dust. Observations at long, sub-millimeter wavelengths can be used to investigate the physical properties in the youngest stages of star formation. Interferometers provide the resolution necessary to resolve small scale structures like dense cores where star formation is expected to occur. CMZoom is the first large area survey of the Central Molecular Zone (CMZ) at high resolution in the submillimeter, allowing us to identify early sites of star formation. The survey uses both the subcompact and compact configurations of the Submillimeter Array (SMA) interferometric radio telescope. The CMZ, or the inner 500 pc of the Milky Way Galaxy, is a high extinction region comprised of hot, dense, and turbulent molecular gas. This region is forming about an order of magnitude fewer stars than predicted based on simple star formation prescriptions. Here, we present new high resolution images of G0.068-0.075, a region from the CMZoom survey, obtained using CASA. We highlight the importance of interferometric observations of different baseline lengths by comparing the spatial information obtained through different configurations. We will use these new images, in conjunction with the rest of the CMZoom survey, to reveal the mechanisms driving star formation at the center of the galaxy.

Rixin Li (University of Arizona)

Andrew Youdin (University of Arizona)
Jacob Simon (University of Colorado)

Topic: Exoplanets, the Solar System and the origins of Stars, Planets and Life

Properties of Planetesimals Formed by the Streaming Instability

In the core-accretion planet formation model, a fundamental problem is how to produce super-kilometer-sized planetesimals out of dust particles in gaseous protoplanetary disks. The Streaming Instability (SI) is a mechanism to concentrate dust aerodynamically in protoplanetary disks. Our high-resolution simulations have shown that nonlinear particle clumping from the SI can trigger gravitational collapse into planetesimals. This poster presents a further diagnosis of the properties of those bound clumps produced in our simulations. We have developed a new clump-finding tool, PLAN (PLanetesimal ANalyzer), to accurately and precisely identify all of the clumps. We confirm one of our previous results that the initial mass function of planetesimals is near-universal regardless of the initial particle size and extend this function to a very low-mass end. PLAN also enables us to investigate the mass and angular momentum distributions within each clump. We report that massive planetesimals tend to be more prograde. In addition, the angular momentum distribution will be useful for future high-resolution studies of gravitational fragmentation and hence may have implications for the formation of binary planetesimals. Such models can be tested with the relatively pristine population of the binary Kuiper Belt Objects. Overall, our results could provide insights for future observations and modeling for planetesimal formation.

Ryan Lynch (Green Bank Observatory)

Jay Lockman (Green Bank Observatory)

Topic: Exoplanets, the Solar System and the origins of Stars, Planets and Life

Wide-Field, High-Resolution 3mm Molecular Imaging with the Green Bank Telescope

Argus+ is a large format radio camera system for the Green Bank Telescope(GBT) that will carry out high-fidelity spectroscopic mapping in themolecule-rich 3mm band. The project builds on the success of the prototype16-pixel Argus 3mm receiver. Argus+ will be nine copies of Argus in asingle dewer, with lower noise amplifiers, for an increase of a factor often in mapping speed. The Argus+ project includes a dedicated spectrometerand improvements to the GBT metrology that will more than double theamount of useful observing time at 3mm. With a footprint of 6'x6', 144pixels, an angular resolution of 6"" to 8"", and the sensitivity of a filledaperture, Argus+ will map fundamental transitions of important speciesover hundreds of square arc-min with a spatial dynamic range of 104 to105. The Argus+ project includes two legacy surveys: a survey of moleculesin the Gould Belt molecular clouds, and a survey of dense gas in nearbygalaxies. These will be carried out by the scientific community and willbe defined through a series of workshops. The Project has a strongeducational component and will involve undergraduates at every stage. Itwill be incorporated into new and existing outreach programs, and willproduce materials for the Green Bank Science Center. Argus+ will beoperated as an open skies facility of the Green Bank Observatory, with themajority of its use being allocated through the normal proposal reviewprocess.

Chris Moeckel (UC Berkeley)

Imke de Pater (UC Berkeley)
Bryan Butler (NRAO)
Bob Sault (University of Melbourne)
Edward Molter (UC Berkeley)

Topic: Exoplanets, the Solar System and the origins of Stars, Planets and Life

Radio Science at Jupiter: the Combined Power of the VLA and Juno

Over the past years, radio observations have constrained foremost the ammonia abundance in the Jovian atmosphere. Understanding the distribution of ammonia and its spatial and temporal variability can help constrain the circulation patterns by identifying regions with up- and downwelling. Juno, the NASA probe currently in a highly elliptical orbit around Jupiter, probes the atmosphere down to several hundred bars and allows to understand the vertical coupling between the various regions of the atmosphere. In the future, the Juno microwave observations are primed to reveal further trace gases constraining Jupiter planetary formation scenarios.

Scans with the Very Large Array (VLA) have shown that the majority of the variations on spatial scales are found in the upper atmosphere (0.1 - 10 bars), an observation that was confirmed by the Juno spacecraft. Therefore, at the times of Juno's perijove passes, we are providing information on the spatial variations of the upper atmosphere by observing a complete rotation of the planet. The measurements span frequencies between 8 - 26 GHz (X, Ku, and K-band), which are then de-projected to provide 2D maps of variations in radio brightness for a given frequency band, where the lower frequencies can probe deeper into the atmosphere.

These spatially resolved maps relate the variations in brightness temperature to changes in the abundance of trace gases, most prominently ammonia. The observed feature range from planetary variations such as the zones and belts to resolving smaller plumes of upwelling ammonia, which are a few thousand kilometers across. These maps represent the current state of the art resolution that can be achieved with the VLA.

As Juno Cam has demonstrated, the atmosphere shows signs of complex interactions on all spatial scale and thus with the VLA current resolution, we are just barely scratching the surface of the planet. The capabilities of ngVLA will allow us to study Jupiter atmosphere on a completely different spatial scale.

Nickalas Reynolds (The University of Oklahoma)

Topics: Exoplanets, the Solar System and the origins of Stars, Planets and Life

Exploring a Gravitationally Unstable Disk, L1448 IRS3B

ALMA Cycle 4 (Band 7; ∼870 microns) observations of the nearby (d∼230 pc) triple protostar system, L1448 IRS3B, have resolved continuum spiral structure originating from an inner (∼60 AU) protostellar binary with a third protostellar companion embedded (∼180 AU) within one of the arms. Current observations and efforts have yet to fully characterize the kinematics of this multiple system, which is needed to confirm if gravitational instability (GI) of the disk formed the multiple system.

The continuum spiral structure does not directly shed light unto the disk kinematics, however, molecular emission provides more clear picture; $C^{17}O$ (J=3-2) traces the warm (> 15K), dense gas of the disk, uncovering information regarding the kinematics therein. Simple analysis shows the protostellar disk is consistent with Keplerian rotation about a central mass of 0.8 $M_{\odot}$ and a disk mass of ∼100 M_J . We model the $C^{17}O$ visibilities using a radiative transfer code (RADMC-3D) in tandem with a Markov-Chain Monte-Carlo (MCMC; emcee) and Bayesian statistics to better constrain the protostellar parameters and examine the disk properties/kinematics.

We further discuss the implications of our results with the formation of stellar multiples and theorize the mechanisms of GI formation in this archetypal system.

Marialis Rosario-Franco (University of Texas at Arlington)

Suman Satyal (University of Texas at Arlington)
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Jitendra Kodilkar (Giant Metrewave Radio Telescope)

Topic: Exoplanets, the Solar System and the origins of Stars, Planets and Life

Searching for the First Exomoon in the Radio Using the Giant Metrewave Radio Telescope (GMRT)

Exoplanetary research has undergone a great deal of development and growth. Achievements in theoretical studies and detection techniques have led to the discovery of over 3,500 exoplanets in ~2,600 planetary systems to date. Despite this great success, the detection of the first exomoon is yet to be accomplished. Motivated by this, we have applied a novel radio-detection method, proposed by Noyola et.al (2014, 2016). The technique is based on a planet-moon interaction observed in the Jupiter-Io system, and Io-controlled decametric radio emissions were used to demonstrate how the presence of exomoons around giant planets might be revealed by the same modulation mechanism. Three targets were observed through the Giant Metrewave Radio Telescope (GMRT); located in Punam, India. Preliminary results of our data analysis will be presented and discussed.

Joshua Tollefson (UC Berkeley)

Imke de Pater (UC Berkeley), Statia Luszcz-Cook (American Museum of Natural History)

Topic: Exoplanets, the Solar System, and the Origins of Stars, Planets, and Life

Constraining Opacity Sources on Neptune with ALMA

Spatially resolved millimeter maps of Neptune reveal brightness temperature variations in the troposphere. These differences are mainly due to latitudinal variations in opacity, but previous maps were unable to resolve the source of this opacity, e.g. CH4, H2S, or ortho/para H2. ALMA provides the high spatial resolution, sensitivity, and wavelength coverage needed to better constrain the abundances of the constituents as a function of latitude. We present ALMA millimeter maps taken in Bands 3 (95-109 GHz), 4 (136-150 GHz), and 6 (224-242 GHz). We find brightness enhancements of 2-4K at Neptune's south pole and depletions of 2-4K at the mid-latitudes, assuming a uniform global model for Neptune's troposphere taken from Luszcz-Cook et al. (2013). Low abundances of microwave absorbers mean decreased opacity, allowing deeper, warmer layers to be probed. Thus, radio brightness enhancements are consistent with subsiding dry air, (south pole), while brightness depletions are consistent with uplifted, wet air (mid-latitudes). The ngVLA will provide full 2D, longitudinally-resolved maps at high spatial resolution in multiple frequencies.

Ci Xue (Department of Chemistry, University of Virginia)

Anthony J. Remijan (National Radio Astronomy Observatory), Andrew M. Burkhardt (Department of Astronomy, University of Virginia) and Eric Herbst (Department of Chemistry, University of Virginia)

Topic: Exoplanets, the Solar System and the origins of Stars, Planets and Life

Spatial Distribution of $C_2H_4O_2$ Isomers in Sagittarius B2(N)

One of the outstanding questions in astrochemical modeling is the relative role of gas-phase and grain-surface reaction processes in forming molecules in astronomical environments. The $C_2H_4O_2$ isomeric triplet found in the interstellar medium consists of glycolaldehyde (CH_2OHCHO), acetic acid (CH_3COOH), and methyl formate ($HCOOCH_3$), whose forming mechanisms involve both gas-phase and grain-surface processes (Hollis et al. 2000). With the ALMA Band 3 observations (Belloche et al. 2016), we report the discovery of weaker, and previously undetected, transitions of the $C_2H_4O_2$ isomers. With these additional unblended transitions and more accurate continuum subtraction, we report the high spatial resolution sub-millimeter maps of the of CH_2OHCHO, CH_3COOH, and $HCOOCH_3$. We stack all the integrated intensity maps of the uncontaminated transitions of each molecule to get their chemical maps. $HCOOCH_3$ and CH_2OHCHO each display two different velocity components, while only one velocity component of CH_3COOH is resolved. Moreover, the distribution of $HCOOCH_3$ is diffuse and offset from the continuum emission, unlike CH_2OHCHO and CH_3COOH, which we find to be co-spatial with the continuum. The difference in the morphology of the three isomers indicates that the three isomers might have different formation mechanisms.