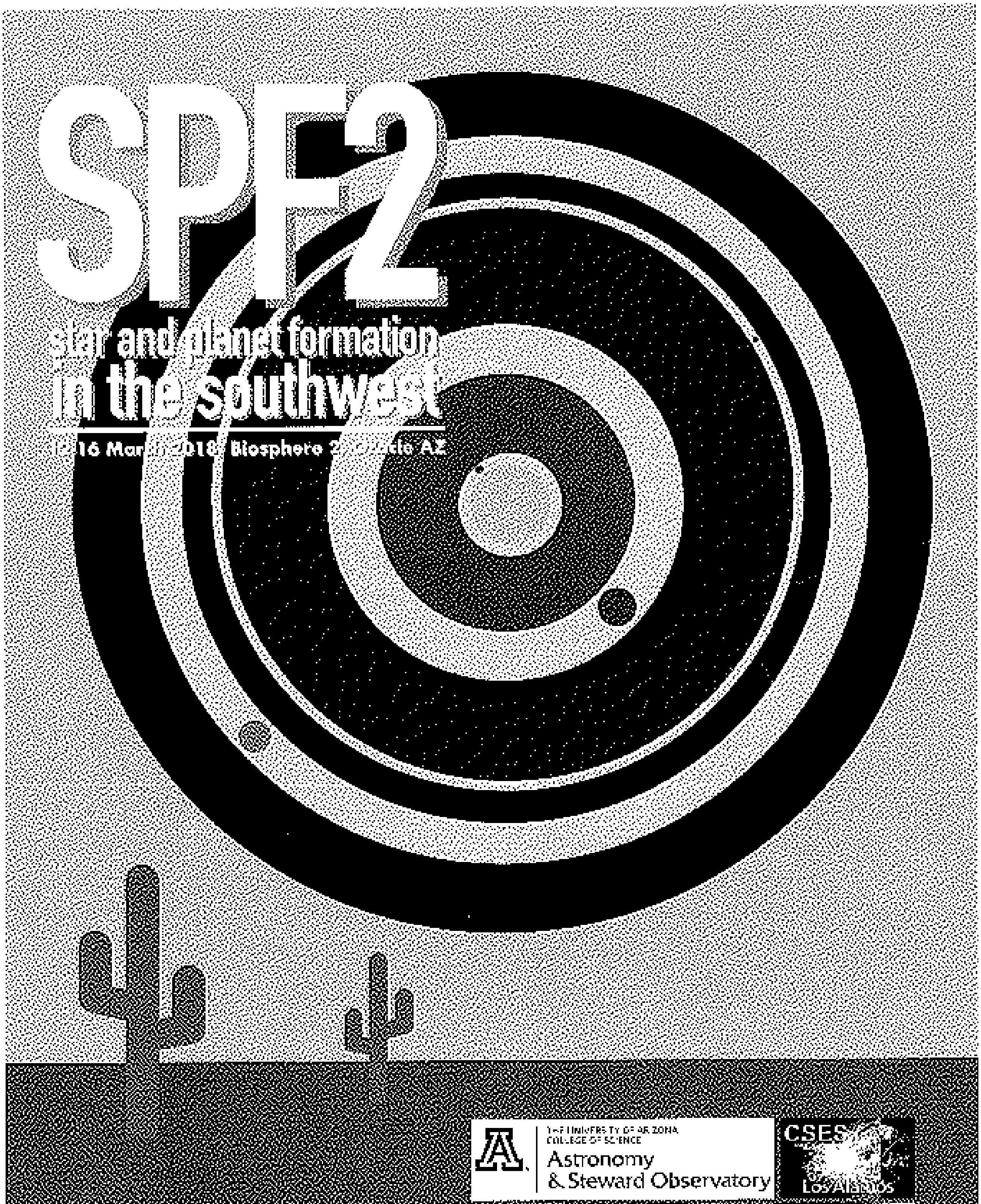
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STAR AND PLANET FORMATION in the SOUTHWEST

March 12 - 16, 2018

Biosphere 2 Center | Oracle Arizona

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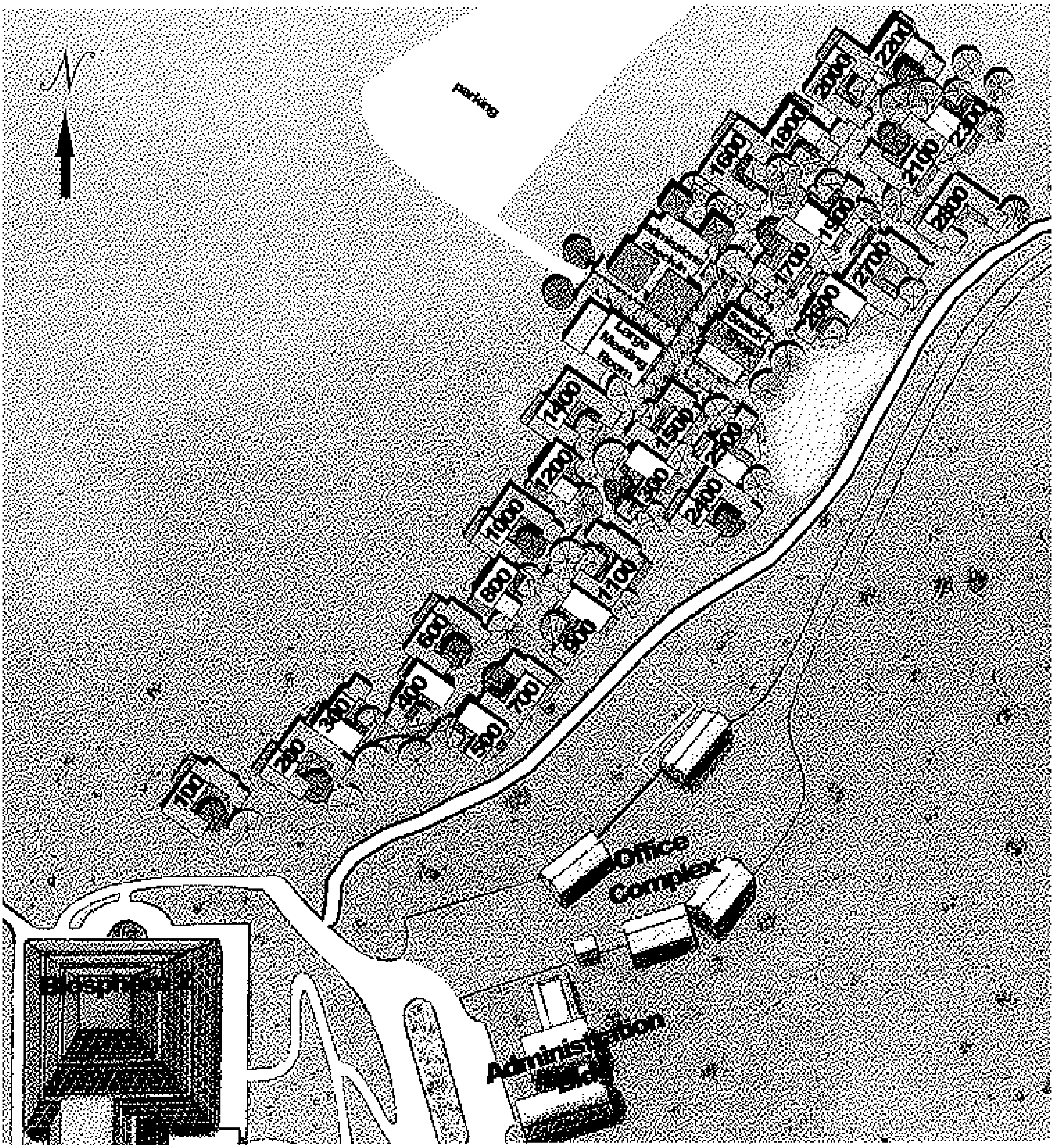
Biosphere 2: Student Village Map



SUNDAY, March 11, 2018

6:00-8:00pm Registration and welcome.

MONDAY, March 12, 2018

STAR FORMATION AND PROTOSTELLAR DISKS

7:30-9:00:	Breakfast
9:00-9:15	Joan Najita (invited): Meeting Overview and Welcome
9:15- 10:00	Helen Kirk (invited review) Dense cores and their substructure
10:00-10:15	Brian Svoboda Starless Clumps and the Earliest Phases of High-mass Star Formation in the Milky Way
10:15-10:30	Will Fischer The Herschel Orion Protostar Survey: Luminosity and Envelope Evolution
10:30-11:00	Coffee Break
11:00-11:45	Matthew Bate (invited review): Star formation and Protostellar disks
11:45-12:00	Nicole Karnath An ALMA + VLA Survey of Orion Protostars: The Youngest Class 0 Objects
12:00-12:15	Tien-Hao Hsieh The early-phase protostellar disk around the VeLLO, IRAS16253-2429
12:15-1:45	Lunch Break
1:45-2:30	John Tobin (invited review). Observations of protostellar disks
2:30-2:45	Kimberly Ward –Duong: Results from the Taurus Boundary of Stellar/Substellar (TBOSS) Survey: Disk Masses from ALMA Continuum Observations
2:45-3:00	Zhoujian Zhang A Pan-STARRS1 Proper-Motion Survey for Young Brown Dwarfs in the Nearest Star-Forming Regions and a Reddening-Free Classification Method for Ultracool Dwarfs

MONDAY (continued)

3:00-3:15	Benjamin Tofflemire Accretion Dynamics in Pre-Main Sequence Binary Systems
3:15-3:45	Coffee
3:45-4:30	Scott Gaudi: (invited review) Exoplanet Statistics: what are we aiming for?
4:30-5:15	Discussion: Linking theory and observations (Stella Offner & Alycia Weinberger)
5:15-6:00	Posters / Happy hour
6:00-8:00	Dinner

TUESDAY, March 13, 2018

PROTOPLANETARY DISKS: MULTI-WAVELENGTHS OBSERVATIONS AND MODELS

7:30-9:00:	Breakfast, etc.
9:00- 9:45	Ilaria Pascucci (invited review): ALMA Surveys of Protoplanetary Disks
9:45-10:00	Megan Ansdell Disk Demographics with ALMA: Gas Disk Radii and Dust Grain Growth
10:00-10:15	Jane Huang High Resolution ALMA Observations of Gas and Dust in Protoplanetary Disks
10:15-10:30	Andrea Banzatti Revealing the evolution of exoplanet-forming disks at 0.01-10 au
10:30-11:00	Coffee Break
11:00-11:45	Kees Dullemond (invited review) Disk Theory Overview
11:45-12:00	Xiao Hu Non Ideal MHD in HL Tau: From Disk Atmosphere To Midplane
12:00-12:15	Kevin Flaherty Weak Turbulence in Protoplanetary Disks as Revealed by ALMA
12:15-12:30	Daniel Cole Outbursts in Protoplanetary Disks due to the Stellar Magnetic Fields Interaction with a Hall Dead Zone
12:30-2:15	Lunch Break
2:15-3:00	Discussion: Disk Turbulence: theory and observations (Meredith Hughes and Jake Simon)
3:00-3:45	Ilse Cleeves (invited Review) Disk Chemistry
3:45-4:00	Stefano Facchini The Molecular View of Disk Substructures

TUESDAY, continued

4:00-4:15	Marco Tazzari A multi-wavelength view of planet forming regions: unleashing the full power of ALMA
4:15-4:45	Coffee break
4:45-5:30	Discussion Session: Many Unsolved Problems in Disks (Jonathan Williams and Jim Stone)
5:30-6:30	Poster Session / happy hour
6:30-8:00	Dinner
8:00-9:30	TAAA: Enjoy the Arizona night sky with small telescopes

WEDNESDAY, March 14, 2018

MORNING EXCURSIONS, AFTERNOON TALKS

7:00-8:00:	Breakfast
8:00- 2:30:	Excursions, options: (1) Hike (2) special biosphere 2 tour
	Lunch
2:30-3:15	Myriam Benisty (invited review): Scattered light imaging of protoplanetary disks
3:15:3:30	Ryan Loomis Evidence for Misaligned Inner and Outer Disks Around AA Tau
3:30:3:45	Miriam Keppler Detection of a planetary-mass companion candidate inside the gap of the transitional disk around PDS70
3:45-4:00	Paolo Cazzoletti Where do the spirals come from? A multi-wavelength, high-resolution study of HD135344b
4:00-4:30	Coffee Break
4:30-5:15	Zhaohuan Zhu (invited review) The disk-planet connection----theory
5:15-5:30	Giovanni Dipierro Dust gaps in protoplanetary discs revealed by ALMA Application to Elias 24
5:30:5:45	Jaehan Bae Rings, gaps, and spiral arms in protoplanetary disks: footprints of forming planets
5:45-6:30	Discussion: Inclusion in astronomy: success stories from our departments (Adam Kraus, Paola Pinilla, Lisa Prato, Meredith Hughes)
6:45-8:45	Dinner

THURSDAY, March 15, 2018

DISKS TO PLANETS

7:30-9:00	Breakfast
9:00-9:45	Phil Armitage (invited review) Planet formation theory
9:45-10:00	Chao-Chin Yang The Streaming Instability in the Dead Zone of a Protoplanetary Disk
10:00-10:15	Djoeke Schoonenberg The Behaviour of Pebbles Around Snowlines in Protoplanetary Disks
10:15-10:30	Gijs Mulders Multi-planet systems as tracers of the inner edges of protoplanetary disks
10:30-11:00	Coffee Break
11:00-11:15	Michael Hammer Planet-induced vortices: The effects of realistic planet formation timescales
11:15–11:30	Rebecca Nealon Discs warped by misaligned planets
11:30-12:15	Discussion: Interpreting disk substructures: Planets or not? (Robin Dong, Paola Pinilla)
12:15-1:45	Lunch
1:45-2:00	Yifan Zhou Cloud Atlas: Rotational Modulations in Planetary Mass/Brown Dwarf Companions
2:00-2:15	Laci Brock Dynamical Masses of Brown Dwarf Binaries as a Proxy for Testing Atmospheric and Evolutionary Models
2:15-3:00	Brenda Matthews (invited review) Debris Disks and Planet Formation
3:00-3:45	Coffee Break

THURSDAY, continued

3:45-4:00	Renata Frelikh Dynamical upheaval in ice giant formation
4:00-4:15	Steve Ertel The HOSTS survey: Exo-zodiacal dust measurements for 30 stars
4:15-4:30	Luca Matra An Empirical Planetesimal Belt Radius - Stellar Luminosity Relation
5:00-6:00	Final poster session / happy hour
6:00-8:30	El Charro Banquet + Conference Summary (Andrew Youdin)

FRIDAY, March 16, 2018

BREAKOUT SESSIONS

7:30-8:30:	Breakfast
8:30-10:00:	ALMA (lead by John Carpenter)
10:00-10:30	Coffee Break
10:30-12:00	Simultaneous break-out sessions: JWST (Jarron Leisenring + Everett Schlawin) and Numerical Methods (Hui Li, Mario Flock, & Phil Armitage)

Starless Clumps and the Earliest Phases of High-mass Star Formation in the Milky Way

Brian Svoboda
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High-mass stars are key to regulating the interstellar medium, star formation activity, and overall evolution of galaxies, but their formation remains an open problem in astrophysics. In order to understand the physical conditions during the earliest phases of high-mass star formation, we report on observational studies of dense starless clump candidates (SCCs) that show no signatures of star formation activity. We identify 2223 SCCs from the 1.1 mm Bolocam Galactic Plane Survey, systematically analyze their physical properties, and show that the starless phase is not represented by a single timescale, but evolves more rapidly with increasing clump mass (Svoboda et al., 2016). To investigate the sub-structure in SCCs at high spatial resolution, we study the 12 most high-mass SCCs within 5 kpc using ALMA. We report previously undetected low-luminosity protostars in 11 out of 12 SCCs, fragmentation equal to the thermal Jeans length of the clump, and, although rare, high-mass starless core candidates with total mass upper limits extending to 60 M sun. While uncertainties remain concerning the star formation efficiency in this sample, these observational facts are consistent with models where high-mass stars form from initially low- to intermediate-mass protostars that accrete most of their mass from the surrounding clump through gravitationally driven cloud inflow.

The Herschel Orion Protostar Survey: Luminosity and Envelope Evolution

Will Fischer
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The theoretical framework for explaining how stars get their mass has been historically divided into two disparate camps. One camp argues that stellar mass assembly is steady and continuous over ~ 0.5 Myr, while the other argues that this process is stochastic, featuring major episodes of accretion concentrated into short bursts. Both scenarios represent extrapolations from other evolutionary phases. Models of steady accretion are adapted from the expected evolution of a cloud core in the absence of a disk, while models of episodic accretion are motivated by the 20th century detection of luminosity outbursts in optically revealed young stars that have protoplanetary disks, but where the vast majority of the stellar mass is already in place. There must be a transition between these two modes, from core- to disk-dominated accretion, but this has not previously been demonstrated from observations. These radically different scenarios can be disentangled by analyzing the luminosity evolution of statistically important populations of protostars.

With the Herschel Orion Protostar Survey (HOPS), we obtained well-sampled spectral energy distributions from 1.2 to 870 μm for over 300 protostars in Orion, the largest population in a single star-forming region in the nearest 500 pc. With these data, I place the protostars on a bolometric luminosity and temperature (BLT) diagram. The histogram of bolometric temperature is roughly flat, while the median luminosity decreases by a factor of four over the protostellar phases. The spread in luminosities at each temperature is three orders of magnitude. In a related study, we compared Spitzer and WISE photometry of the protostars and found that the average interval between luminosity outbursts in a single protostar may be as short as 800 years. I show that, while episodic accretion clearly occurs, the Orion BLT diagram can be explained by envelope masses that decline exponentially with time to form a range of stellar masses.

Figure: Bolometric luminosities and temperatures of 330 young stellar objects in Orion, 315 of which are protostars. Dashed lines show the traditional divisions into Class 0, Class I, and Class II. Large diamonds show decreasing median luminosities in bins of increasing bolometric temperature, and the associated lines show the interquartile luminosity range in each bin. Histograms show the marginal distributions for bolometric luminosity (peaked) and bolometric temperature (flat). The slightly tilted line connects the pre- and post-burst positions of one episodic accretor, while boxes mark the post-burst locations of three others.

INVITED REVIEW:
Star Formation and Protostellar Disks

Matthew Bate
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I will give an overview of how low-mass stars form in molecular clouds, discussing various processes that are involved in determining the statistical properties of stars such as their mass function, multiplicity, and the star formation rate. I will then turn to protostellar disc formation. I will examine the processes involved in disc formation, and present results from the first study of protostellar disc population synthesis that allows us to begin to quantify the diversity and statistical properties of young discs.

An ALMA + VLA Survey of Orion Protostars: The Youngest Class 0 Objects

Nicole Karnath
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Using ALMA (continuum at 0.87 mm) and the VLA (Ka-band, 9 mm), we present 40 AU resolution images of 24 of the most deeply embedded protostars in the Orion Molecular Cloud. These have weak or no detected emission at 24 μm from Spitzer but are bright at 70 μm and were first identified by the HOPS (Herschel Orion Protostar Survey) program. Due to their rarity, these deeply embedded protostars have estimated ages < 25,000 yrs (Stutz et al. 2016).

We image the inner 200 AU regions of these young protostars with the ability to resolve disks and map the inner envelope structures. We find a variety of morphologies including three binaries, a few disk-like structures, extended emission from the envelope and compact, barely resolved protostars. We estimate the mass in this inner region and compare with other disk masses in the literature. Discrepancies between the VLA and ALMA morphologies are likely due to differences in optical depth. We discuss possible reasons for the different morphologies and whether they represent an early evolutionary sequence.

The early-phase protostellar disk around the VeLLO, IRAS16253-2429

Tien-Hao Hsieh
Academia Sinica Institute of Astronomy and Astrophysics, thhsieh@asiaa.sinica.edu.tw

We present ALMA cycle 4 results toward the Very Low Luminosity Object (VeLLO), IRAS 16253-2429 (hereafter IRAS 16253). IRAS 16253 was considered as a proto-brown dwarf binary system, but the new observation identifies it as a single protostar down to 0.09 (~12 au). Our previous result suggests that IRAS 16253 has experienced a past accretion burst with a mass accretion rate > 1.5*10^-5 Msun/yr within 10,000 yr. This result, together with the detection of bipolar outflows, implies an existence of gravitational unstable disk which delivered a 0.002 - 0.003 solar mass of material on to the central protostar in the past burst. We find a tiny dusty disk with a size of ~20 au through the 1.3 mm continuum emission. Rotational supported disk with a size of ~80 au is found from CO (21) and C18O (21) observations. The mass of the central star derived from the rotation curve of the gaseous disk is ~0.07 Msun, which is already close to the stellar mass.The mass ratio between the central star+disk system and natal core (0.20.5 Msun) is 1540%. This implies that the central object have enough mass reserver to form a low-mass star with hydrogen burning. The mass of the gaseous disk is estimated to be ~0.005 Msun, ~7% of that of the protostar, and is about 2 times larger than that of the accreted material during the past burst.

INVITED REVIEW:
Observations of Protostellar Disks

John Tobin
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Protostellar disks are thought to form early in the star formation process due to conservation of angular momentum. These disks are the future sites of planet formation, but may also be the sites of binary/multiple star formation if the disk is massive enough to be gravitationally unstable. Our understanding of the current properties of protostellar disks has evolved considerably during the past 5 years thanks to the VLA and ALMA. Moreover, numerous proto-binaries/multiples have been found in nearby star forming regions on 100s of AU scales which appear to be consistent with formation from a disk. I will review the significant observational progress in the field that has advanced our understanding of disk formation and where disk formation research may go in the future.

Results from the Taurus Boundary of Stellar/Substellar (TBOSS) Survey: Disk Masses from ALMA Continuum Observations

Kimberly Ward-Duong
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We report 885μm ALMA continuum flux densities for 24 Taurus members spanning the stellar/substellar boundary, with spectral types from M4 to M7.75. Of the 24 systems, 22 are detected at levels ranging from 1.0-55.6 mJy. The two non-detections are transition disks, though other transition disks in the sample are detected. Converting ALMA continuum measurements to masses using standard scaling laws and radiative transfer modeling yields dust mass estimates ranging from ~0.3-20MEarth. The dust mass shows a declining trend with central object mass when combined with results from submillimeter surveys of more massive Taurus members. The substellar disks appear as part of a continuous sequence and not a distinct population. Compared to older Upper Sco members with similar masses across the substellar limit, the Taurus disks are brighter and more massive. Both Taurus and Upper Sco populations are consistent with an approximately linear relationship in Mdust to Mstar, although derived power-law slopes depend strongly upon choices of stellar evolutionary model and dust temperature relation. The median disk around early M-stars in Taurus contains a comparable amount of mass in small solids as the average amount of heavy elements in Kepler planetary systems on short-period orbits around M-dwarf stars, with an order of magnitude spread in disk dust mass about the median value. Assuming a gas:dust ratio of 100:1, only a small number of low-mass stars and brown dwarfs have a total disk mass amenable to giant planet formation, consistent with the low frequency of giant planets orbiting M-dwarfs.

A Pan-STARRS1 Proper-Motion Survey for Young Brown Dwarfs in the Nearest Star-Forming Regions and a Reddening-Free Classification Method for Ultracool Dwarfs

Zhoujian Zhang
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Young brown dwarfs are of prime importance to investigate the universality of the low-mass initial mass function (IMF). Based on photometry and proper motions from the Pan-STARRS1 (PS1) 3pi survey, we are conducting the widest and deepest brown dwarf survey in the nearby star-forming regions, Taurus-Auriga (Taurus) and Upper Scorpius (USco). Our work is the first to measure proper motions for brown dwarf candidates in Taurus and USco over such a large area and long time baseline (~15 yr) with such high precision (~4 mas/yr). Since extinction complicates spectral classification, we have developed a new approach to quantitatively determine reddening-free spectral types, extinctions, and gravity classifications for mid-M to late-L ultracool dwarfs (~100-5 M_Jup) using low-resolution near-infrared spectra. So far, our spectroscopic follow-up has increased the substellar and planetary-mass census of Taurus by ~50% and almost doubled the substellar census of USco, constituting the largest single increases of brown dwarfs and free-floating planets found in both regions to date. Most notably, our new discoveries reveal an older (>10 Myr) low-mass population in Taurus, in accord with recent studies of the higher-mass stellar members. The mass function appears to differ between the younger and older Taurus populations, possibly due to incompleteness of the older stellar members or different star formation processes. Upon completion, our survey will establish the most complete substellar and planetary-mass census in both Taurus and USco associations.

Accretion Dynamics in Pre-Main Sequence Binary Systems

Benjamin Tofflemire
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Over the past thirty years, a detailed picture of star formation has emerged that highlights the significance of the interaction between a pre-main sequence star and its protoplanetary disk. This star-disk interaction has been extensively characterized in the case of single stars, revealing implications for pre-main sequence stellar evolution and planet formation. Many stars, however, form in binary or higher-order systems where orbital dynamics fundamentally alter this star-disk interaction. In short-period binaries, orbital resonances are predicted to carve out the center of the protoplanetary disk, leading to periodic accretion streams that bridge the gap between a circumbinary disk and the central stars. To test these predictions, we have conducted an intensive observational campaign combining multi-color photometry and high-resolution spectroscopy in time-series. Within these data we search for periodic trends in the accretion rate and in the velocity structures of accretion-tracing emission lines. I will present results highlighting the detection of periodic enhanced accretion events in two eccentric binaries (DQ Tau and TWA 3A) and evidence for preferential accretion onto the TWA 3A primary. Both results are presented in the context of recent hydrodynamic simulations of binary accretion.

INVITED REVIEW:
Exoplanet Statistics: What are we aiming for?

Scott Gaudi
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Understanding the demographics of exoplanets is a requirement for developing an observationally-constrained model of the formation and migration of exoplanets. Exoplanet discovery surveys have revealed a large diversity of systems, many of which look nothing like our own solar system. The overwhelming majority of planets discovered have been detected indirectly by the radial velocity method, the transit method, or the microlensing method, and a few have been directly detected. The physical parameters that produce the observables in these methods are fundamentally different, and consequently, the properties of the planetary systems they reveal are also different. In other words, each technique is sensitive to planets in a given region of parameter space (e.g., mass–orbital period space), and is sensitive to a different properties of the planets, with varying degrees of overlap with regions probed by other techniques. The ultimate goal is to provide a self-consistent statistical census of exoplanets over as wide a range of planet and host star properties as possible. I will describe the progress toward this goal to date, and the future prospects and challenges to achieving that goal in the near- and far-term future.

INVITED REVIEW
ALMA Surveys of Protoplanetary Disks

Ilaria Pascucci
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The sensitivity of the Atacama Large Millimeter Array has recently enabled to survey nearly all planet-forming disks in nearby star-forming regions at moderate spatial resolution. I will provide an overview of these surveys, discuss which disk physical properties have been constrained and emerging trends. I will also show how parallel optical surveys that homogeneously characterized the stellar properties of the ALMA targets have enhanced the value of the ALMA surveys. Finally, I will examine the spread in disk properties relevant to planet formation and make a link to the diversity of planetary systems.

Disk Demographics with ALMA: Gas Disk Radii and Dust Grain Growth

Megan Ansdell
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We present new high-sensitivity, high-resolution ALMA Band 6 observations of a complete sample of protoplanetary disks in the young (~1-3 Myr) Lupus star forming region, covering the 1.33 mm continuum as well as the 12CO, 13CO, and C18O J=2–1 lines. The typical spatial resolution of our observations is 0.25″ with a continuum sensitivity that corresponds to disk dust masses of 0.1 Earth masses. We apply a "Keplerian masking" technique to enhance the signal-to-noise ratios of the 12CO zero-moment maps, allowing us to measure gas disk radii for 21 Lupus disks; we find that the gas disks are universally larger than the millimeter dust disks by an average factor of two, likely due to a combination the optically thick gas emission as well as the growth and inward drift of the dust. Using the gas disk radii, we calculate αvisc, the dimensionless viscosity parameter, finding a broad distribution spanning several orders of magnitude and no correlations with other disk or stellar parameters. Additionally, by combining our 1.33 mm continuum fluxes with our previous 890 μm continuum observations, we calculate the millimeter spectral index, αmm, for 62 Lupus disks; we find a clear anti- correlation between αmm and millimeter flux, which suggests that grain growth is faster in higher-mass disks, but may also reflect larger optically thick components in these more massive disks. In sum, this work demonstrates the continuous stream of new insights into disk evolution and planet formation that can be gleaned from large-scale ALMA disk surveys.

High Resolution ALMA Observations of Gas and Dust in Protoplanetary Disks

Jane Huang
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There is mounting observational evidence that complex substructures are common in the dust emission of protoplanetary disks, but the distribution of molecular gas has so far not been as well-characterized. Yet, the molecular gas distribution and composition are fundamental for governing how material is incorporated into new planets. Due to its proximity and nearly face-on orientation, the TW Hya disk provides the best opportunity to study gas disk structures. I will present deep ALMA observations of 12CO in the TW Hya disk at a spatial resolution of 8 AU, representing the most detailed images so far of molecular emission in a protoplanetary disk. The CO emission shows two prominent radial breaks, which radiative transfer modeling indicates can be reasonably reproduced by a steep decrease in the CO column density at a radius of 15 AU, followed by a secondary peak at a radius of 70 AU. These features may be a consequence of either substructures in the underlying gas disk or of radially varying CO depletion affecting much of the extent of the warm gas layer. Finally, I will compare and contrast the morphology of the TW Hya observations to other sources imaged in our recently completed high angular resolution ALMA survey probing scales of 5 to 10 AU in protoplanetary disks.

Revealing the evolution of exoplanet-forming disks at 0.01-10 au

Andrea Banzatti
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I will present results from a multi-wavelength and multi-tracer campaign to observe the evolution of protoplanetary disks at 0.01-10 au at the time of exoplanet formation. The backbone of this work is the combined analysis of recent surveys of moderate-to-high-resolution spectroscopy (R ~ 700- 100,000) of molecular gas emission at infrared wavelengths (2.9-35 um), as collected from a suite of instruments on the ground and in space (VLT-CRIRES, VLT-VISIR, Spitzer-IRS, Keck-NIRSPEC, IRTF-ISHELL). I will present and discuss three major findings of this campaign, as published in a series of papers in the last few years: 1) the location and excitation of CO gas reveals the formation of disk cavities and gaps in the 0.01-10 au disk region, 2) these cavities show a large depletion of both dust and gas, with some structures that models propose to be related to planet-disk interactions, and 3) disk chemistry evolves during formation of these cavities, with inner disks being dried-up from their water vapor. I will discuss these discoveries in the context of the increasingly detailed picture of the evolution of exoplanet-forming disks at < 10 au, and I will mention the new directions that we are now starting to investigate in synergy with HST observations of residual gas in transitional disks, the evolution of disk-dispersing winds, and the detailed thermo-chemical modeling of inner disk cavities.

INVITED REVIEW
Disk Theory Overview

Kees Dullemond
ITA Heidelberg, dullemond@uni-heidelberg.de

Resolved images of protoplanetary disks of recent years are displaying several clearly defined large scale structures, including rings, spirals and warps. Are they signposts of planet formation or are other processes at play? In this talk I will review some of the recent theoretical proposals at explaining these features.

Non Ideal MHD in HL Tau: From Disk Atmosphere To Midplane

Xiao Hu
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Recent high resolution observations of HL Tau provide detailed structure of rings in its circumstellar disk. Origin of these rings has been widely investigated through different theoretical assumptions: snow lines, planet disk interactions, and gravitational instabilities of the disk itself. In this work we perform global non-ideal MHD simulations with Athena++ to model the HL-Tau disk. The disk ionization structure is provided by global dust evolution models. We take ambipolar diffusion together with Ohmic diffusion as the major non-ideal MHD effect. We find the temperature in disk atmosphere is critical to MHD process at disk midplane. This gives more constraint on non global disk modelling.

Weak Turbulence in Protoplanetary Disks as Revealed by ALMA

Kevin Flaherty
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Turbulence within protoplanetary disks plays a crucial role in the formation and evolution of planets, through its influence on processes ranging from the collisional velocity of small dust grains to the ability of gas-giant planets to open gaps in the disk. Despite this importance, few direct observational constraints on its strength exist. I will report on our ongoing effort to constrain turbulence using ALMA observations of CO emission from protoplanetary disks. Building on our upper limit around HD 163296 (<0.05cs), we find evidence for weak turbulence around TW Hya (<0.08cs), suggesting that weak turbulence is not unique to the disk around HD 163296. I will also discuss observations of CO/13CO/C18O from around V4046 Sgr, DM Tau, and MWC 480 that will be used to further expand the turbulence sample, covering a range of radiation fields, stellar masses, and evolutionary states.

Outbursts in Protoplanetary Disks due to the Stellar Magnetic Field's Interaction with a Hall Dead Zone

Daniel Gole
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We present modeling of a new mechanism that results in cyclic behavior and episodic accretion events in protoplanetary disks. In the inner disk, a Hall-effect dominated dead zone (region of low turbulence and accretion velocity) is expected to exist. These dead zones have been shown to exhibit dichotomous behavior depending on the alignment of the net vertical magnetic field in the disk relative to the spin axis -- they are active for an aligned field and dead for an anti-aligned field. We show that magnetic field contributed to the inner region of the disk (~0.1 AU) from the star is able to diffuse outward to trigger bursts of accretion from these dead zones on the scale of ~1 AU. We model this mechanism in 1 dimension by self-consistently evolving the surface density and net magnetic field of the disk. This model reveals several different types of cyclic behavior and episodic events that can occur for various stellar and disk parameters. We demonstrate that under certain conditions this mechanism is able to produce events similar in time-scale and magnitude to observed EXor outbursts. We calculate some simple observable features of this behavior including light curves and multi-temperature black body spectra as a function of time.

INVITED REVIEW
Disk Chemistry

Ilse Cleeves
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Major leaps in sensitivity and spatial resolution afforded by the Atacama Large Millimeter/Submillimeter Array (ALMA) have opened up the field of protoplanetary disk chemistry in recent years. Both continuum and molecular emission show complex radial emission patterns (e.g., rings, gaps), and even asymmetry. I will review recent results and new puzzles ALMA has uncovered regarding our evolving picture of the protoplanetary disk environment, highlighting the role of energetic processes originating from the host star and the environment. In addition, these very processes appear to play a more dynamic role in disk chemistry than previously assumed, opening up possibilities for astrochemistry as a new kind of "time domain" science.

The Molecular View of Disk Substructures

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High angular resolution observations of protoplanetary disks are showing a variety of sub-structures, where gaps and rings in particular seem to be a common feature shared by many systems. Until now, such structures have been detected mostly in continuum, both in the (sub-)mm and in NIR scattered light maps, tracing the distribution of dust particles. A variety of models has been invoked to interpret the observations, ranging from embedded protoplanets to dust opacity variations at condensation fronts, and many other physical mechanisms. In this talk, I will show how observations of molecular lines detected with ALMA can help distinguishing between these scenarios. By combining hydrodynamical simulations of gas and dust with thermo-chemical models, I estimate gas temperatures and chemical gradient across the gaps, and predict molecular emission maps for different gap opening mechanisms. In the planetary hypothesis, simultaneous observations of thermal continuum and molecular lines can be used to infer the mass of the planets carving the observed gaps.

A Multi-wavelength View of Planet Forming Regions: Unleashing the Full Power of ALMA

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Observations at sub-mm/mm wavelengths allow us to probe the solids in the interior of protoplanetary disks, where the bulk of the dust is located and planet formation is expected to occur. However, the actual size of dust grains and the physical properties of the disk interior are still largely unknown due to the observational limits of past sub-mm/mm studies. ALMA, thanks to its exquisite resolution and sensitivity, is an unprecedented tool to study grain growth in large samples of disks.

In my contribution I will present the recent analysis of spatially resolved ALMA Band 7 observations of more than 20 protoplanetary disks in the Lupus star forming region. Using a physical model for their sub-mm emission, we have been able to constrain their structure, obtaining a tentative evidence of a disk size-disk mass correlation (Tazzari et al. 2017, A&A in press, arXiv:1707.01499).

As a further step to understand the trends that are emerging in the ALMA surveys of disks (e.g., Ansdell et al. 2016, ApJ 828 46), I will illustrate the new results of a combined analysis of ALMA Band 7 and Band 3 observations of more than 30 Lupus protoplanetary disks (Tazzari et al., in prep.).
I will show the constraints that we derive on the dust properties of these disks and how they compare to those in other star forming regions.

Finally, I will introduce GALARIO (Tazzari, Beaujean and Testi, 2017, submitted to MNRAS, arXiv: https://arxiv.org/abs/1709.06999, code: https://github.com/mtazzari/galario), an easy-to-use GPU Accelerated Library for the Analysis of Radio Interferometry Observations that provides the speedup needed to fully exploit the wealth of information delivered by ALMA. I will demonstrate with examples that GALARIO allows for an extensive investigation of the structure of protoplanetary disks in a short time (e.g., Fedele, Tazzari et al. 2017, A&A in press, arXiv: https://arxiv.org/abs/1711.05185).

INVITED REVIEW
Scattered Light Imaging of Protoplanetary Disks

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Almost three thousand confirmed exoplanets have been detected so far, displaying a great diversity in their natures and architectures. Such a diversity might indicate a wide variety in the initial conditions for their formation in the circumstellar disks, and motivates a thorough study of these disks. While detecting forming planets, still embedded in their host disk, is still extremely challenging, one can aim to look for indirect signatures and imprints of their presence. In the recent years, the new generation of infrared imaging instruments with advanced adaptive optics (e.g. SPHERE, GPI) has produced stunning images of protoplanetary disks, which have shown that small-scale features (rings, spirals, dips, shadows…) are ubiquitous in disks. These features have interestingly been observed in systems with a broad range of stellar properties and age. In this talk, I will review the most recent scattered light observations of protoplanetary disks and will discuss what the detected asymmetric features might trace and imply, in the context of disk evolution.

Evidence for Misaligned Inner and Outer Disks Around AA Tau

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Photometry from exoplanet surveys suggests that so-called dipper systems with quasi-periodic dimming events are common. All generally accepted mechanisms for this behavior require systems that are viewed close to edge-on, but recent ALMA observations of the outer disks of these systems have found a wide range of inclinations. In particular, the mm dust continuum of the archetypical dipper system, AA Tau, has been shown to have a modest inclination of 59L1L. This tension can be resolved if the inner and outer disks of such systems are misaligned, with the inner disk remaining close the edge-on and the outer disk occupying a range of inclinations. Kinematic signatures from molecular gas observations around AA Tau provide indirect evidence for such an orientation, and recent ALMA and SPHERE observations of other systems suggest similar geometries.

In this talk, we present new high resolution (~7 AU) ALMA observations of AA Tau which provide direct evidence for the suspected inner and outer disk misalignment. We show how shadowing from the now resolved inner disk can cause a temperature asymmetry in the dust rings in the outer disk, creating the non-axisymmetric dust features previously reported in the system. Combining these constraints with previous observations of the stellar jet, we suggest a high stellar obliquity of ~45r¨. Such high stellar obliquities are not commonly observed for cool stars such as AA Tau at later evolutionary stages (the Kepler dichotomy), but have been theorized to exist at early stages of star formation. We briefly discuss the implications of the misalignment seen around AA Tau for the eventual geometry of its forming exoplanetary system, as well as the possible ramifications for planetary organic inheritance.

Detection of a Planetary-mass Companion Candidate Inside the Gap of the Transitional Disk Around PDS70

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Transition disks mark a key evolutionary stage of the planet formation process and their study is of prime interest to understand the physical and chemical conditions under which planet formation takes place. Only few detections of companions within these disks exist, and many of them are currently under debate. We analyse new and archival scattered-light images of the transitional disk around PDS70 in polarised light and total intensity, making use of the VLT/SPHERE, VLT/NACO and Gemini/NICI instrument. We report on the detection of a close (~200 mas) bound companion candidate within the gap of the disk. The detection is confirmed at five different epochs and in three near-infrared filter bands (H, K, L). The analysis of its SED implies the presence of a planetary-mass companion. Furthermore, we confirm the previous detection of a large gap with a radius of <60 au in the disk and detect for the first time scattered light from the inner disk. The images of the disk show evidence of a complex azimuthal brightness profile that we discuss in context of the grain sizes.

Where Do the Spirals Come From? A Multi-wavelength, High-resolution Study of HD135344b

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Recent observations of protoplanetary disks in both optical/near-infrared scattered light and (sub-)mm continuum emission have revealed complex structures such as spirals, rings and vortices in micron- sized and mm-sized respectively. Planets are often invoked as an explanation, but the number of planets and their location are degenerate, and the same system can often be explained by more than one scenario. Moreover, most of the time simulations are only able to reproduce the structures observed in one wavelength at the time, missing the information provided by differently sized dust grains. In fact, no clear connection between the structures observed in scattered light and mm has so far been found. HD135344B is a bright transition disk showing perfectly symmetrical spiral arms at near-IR and asymmetric structures at mm-wavelengths at the same time, and an ideal candidate to look for this missing connection. We present new 0.06 resolution ALMA Cycle 4 and 5 observations of this object in Band 3 (3 mm) and Band 4 (2 mm). A combination of these optically thin observations with our previous data at shorter wavelengths will allow a study the spectral index and the dust properties inside the asymmetry through a multi-wavelength analysis, and thus to determine whether or not dust is being trapped inside a massive vortex. Ultimately, we will be able to test whether the asymmetric structure is massive enough to launch the spiral arms observed at near-IR and if a single, massive inner planet is sufficient to explain micron and mm wavelength observations simultaneously, as proposed in van der Marel, Cazzoletti et al. 2016.

INVITED REVIEW
The Disk-planet Connection—Theory

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The interaction between young planets and protoplanetary disks is a two fold story. First, the presence of young planets can change the disk structure and affect disk dynamics, such as producing gaps, vortices, spirals, and leading to disk accretion. These large scale structures have been observed with high contrast imaging and radio interferometric techniques. Whether these observed structures is associated with young planets is still heavily debated. Second, the presence of the disk affects the planet's formation and growth, such as pebble accretion, core growth, and the formation of circumplanetary disks. The dynamics happening at these small scales may be the key to probe young planets directly. I will summarize recent theoretical development on planet-disk interaction from both sides, and their implications for protoplanetary disk observations and exoplanets.

Dust Gaps in Protoplanetary Discs Revealed by ALMA Application to Elias 24

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Recent spectacular spatially resolved observations of gaps and ring-like structures in nearby dusty protoplanetary discs have revived interest in studying gap-opening mechanisms. WeL-describe the two distinct physical mechanisms for dust gap opening by embedded planets in protoplanetary discs: I) A mechanism where low mass planets, that do not disturb the gas, open gaps in dust by tidal torques assisted by drag in the inner disc, but resisted by drag in the outer disc; and II) The usual, drag assisted, mechanism where higher mass planets create pressure maxima in the gas disc which the drag torque then acts to evacuate further in the dust.
We also present Atacama Large Millimeter/sub-millimeter Array (ALMA) Cycle 2 observations of the 1.3 mm dust continuum emission of the protoplanetary disc surrounding the T Tauri star Elias 24. The dust continuum emission map reveals a dark ring at a radial distance of ~ 65 au from the central star, surrounded by a bright ring at ~ 81 au. In the outer disc, the radial intensity profile shows two inflection points at ~ 99 and 121 au respectively. We perform global three-dimensional smoothed particle hydrodynamic gas/dust simulations of discs hosting a migrating and accreting planet. Combining the dust density maps of small and large grains with three dimensional radiative transfer calculations, we produce synthetic ALMA observations of a variety of disc models in order to reproduce the gap- and ring-like features observed in Elias 24. We find that the dust emission across the disc is consistent with the presence of an embedded planet with a mass of 0.7 MJ at an orbital radius of ~ 60 au. Our model suggests that the two inflection points in the radial intensity profile are due to the inward radial motion of large dust grains from the outer disc. The surface brightness map of our disc model provides a reasonable match to the gap- and ring-like structures observed in Elias 24, with an average discrepancy of ~ 5 % of the observed fluxes around the gap region.

Rings, Gaps, and Spiral Arms in Protoplanetary Disks: Footprints of Forming Planets

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Thanks to ALMA and optical/infrared telescopes equipped with adaptive optics, recent high-resolution observations have imaged a plethora of detailed structures in protoplanetary disks, ranging from concentric gaps and rings to spiral arms. Since these footprints of newly-born planets are more readily detected than planets themselves in most cases, understanding the mechanism by which the structures form is crucial to constrain the masses and positions of yet unseen planets, and ultimately to gain insights into planet formation processes. In this talk, I will present recent improvements in our understanding of planet-disk interactions. First, I will show that one planet can open multiple gaps in its host disk, as spiral arms launched by a planet steepen into shocks at different radial locations in the disk. I will then explain the mechanism by which a planet excites multiple spiral arms. Finally, I will present some examples of which the characteristics of observed gaps, rings, or spiral arms are used to infer the masses and/or positions of the planets responsible for creating the structures.

INVITED REVIEW
Planet Formation Theory

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The study of planet formation has been revolutionized by recent observational breakthroughs, which have allowed the detection and characterization of extrasolar planets, the imaging of protoplanetary disks, and the discovery of the Solar System's Kuiper Belt. In this talk I will review some of the astrophysical processes that shape planetary systems, including the formation of planetesimals, terrestrial planets, and gas giants. I will highlight the areas where more research and new observations are needed.

The Streaming Instability in the Dead Zone of a Protoplanetary Disk

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The streaming instability has been a promising mechanism to drive the formation of kilometer-scale planetesimals in protoplanetary disks. To trigger this process, it is argued that loading of solid materials onto the mid-plane by sedimentation needs to be efficient and thus a quiescent gaseous environment is required. It is often believed that a dead-zone or disk-wind structure created by non-ideal MHD effects can provide such an environment. By simulating a gas-dust disk with a dead zone and particle-gas mutual drag force, however, we find that centimeter-sized particles do not sediment appreciably more than those in ideal magneto-rotational turbulence, resulting in a vertical scale height one order of magnitude larger than in a laminar disk. Contrary to the expectation that this should curb the formation of planetesimals, we find that strong clumping of solids still occurs in the dead zone with a solid abundance of a few percent, a similar condition found in laminar environment. These results may lead to interesting consequences in the formation of planetesimals by the streaming instability and in the formation of planetary cores by pebble accretion.

The Behaviour of Pebbles Around Snowlines in Protoplanetary Disks

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An interesting region in protoplanetary disks is the snowline - the radial distance from the star beyond which water is in the form of solid ice. The snowline can be the preferred location for the formation of the first generation of so-called planetesimals: kilometre-sized bodies akin to asteroids. Icy pebbles that are spiralling to the star due to gas drag evaporate when they cross the snowline, thereby feeding the region inside the snowline with water vapour and silicate grains. Due to the steep gradient in the concentration of water vapour across the snowline, turbulent diffusion leads to transport of water from within the snowline to outside of it, where it recondenses onto icy pebbles. Thanks to this process a local pile-up of icy pebbles in an annulus outside the snowline is materialised, which can become large enough to trigger the streaming instability. Streaming instability then leads to clumps of pebbles that subsequently collapse under their own gravity to form planetesimals.

In this talk I will describe the dynamical model of the snowline presented in Schoonenberg & Ormel (2017) and our results regarding the plausibility of reaching streaming instability conditions near the snowline. The effect of the composition of icy pebbles in the outer disk on the results will also be discussed. Furthermore, it has recently been reported that ALMA has observed for the first time the snowline in a protoplanetary disk (Cieza et al., 2016). The host star in question, V883 Ori, is currently undergoing a FU Ori-type outburst and is therefore very luminous, pushing the snowline in its surrounding disk out to such a large distance that it was detectable with ALMA. I will talk about what the ALMA observations of the snowline in the disk around V883 Ori can tell us about the properties of pebbles in this disk (Schoonenberg, Okuzumi & Ormel, 2017).

Multi-planet Systems as Tracers of the Inner Edges of Protoplanetary Disks

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The exoplanet population observed with Kepler provides a unique view on the inner edges of protoplanetary disks where planets either formed or stalled their migration. The orbital architectures of multi-planet systems provide crucial constraints on how and where these planets formed. Because the majority of planets in multi-planet systems do not transit their host stars and remain undetected, our view of them is biased and statistical corrections are needed to estimate the properties of multi-planet systems.
I will present a new study on the orbital architectures of planetary systems using the latest Kepler data release, taking into account planet detection efficiency and multi-transit probability for an unbiased view of the population of planetary systems. We identify a common system architecture, where the locations of the innermost planets are clustered around an orbital period of 10 days (0.1 au) and subsequent planets extend out to the habitable zone at ~1 au, and possibly farther. This architecture is reminiscent of the convergent migration of planets that is halted at the protoplanetary disk inner edge. Planets with orbital periods much shorter than Mercury and Venus accompany the majority of exoplanets in the habitable zone, though they often remain undetected in transit surveys. We estimate that orbital architectures like the solar system are rare and occur in less than 10% of planetary systems and around less than 1% stars, reinforcing the view that the solar system is an outlier in the distribution of exoplanets.

Planet-induced Vortices: The Effects of Realistic Planet Formation Timescales

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Several recent observational studies using ALMA have discovered transition disks with high-contrast crescent-shaped asymmetries in the dust, a feature that may be explained by dust-trapping vortices generated by gap-opening giant planets. Most previous numerical studies of vortices often neglect the time it takes to grow a planet to Jupiter-size, a process that may last more than 1000 orbits. In this work, we use two-fluid (gas and dust) hydrodynamical simulations and synthetic ALMA images to show that more realistic planet formation timescales result in vortices that are much weaker and look very different, if they even form at all. These weaker vortices have (i) shorter lifetimes, (ii) more elongated azimuthal extents, and (iii) lower over-densities -- all by a factor of two or more compared to the more concentrated vortices induced by planets that were grown less realistically in less than 100 orbits. Additionally, the wide elongated shapes of these vortices make them much less efficient at trapping dust directly in the center of the vortex. As a result, these elongated vortices may have flatter azimuthal intensity profiles or off-center intensity peaks, making them easy to distinguish from their more concentrated counterparts in observations. Lastly, we compare our synthetic images to those from recent disk surveys, and identify candidate vortices with elongated shapes.

Discs Warped by Misaligned Planets

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Current observations from ALMA have identified unique features in protoplanetary discs around young stars, including warps in the disc (e.g. TW Hya, HD 100453 and HD 135344B) and strongly misaligned inner discs (e.g. HD 100546). For these systems in particular, observations rule out the influence of a secondary star suggesting that as yet unseen planets may be the cause. A planet that is capable of driving these features in the disc would be required to maintain an orbit that is inclined to the disc plane on long timescales, in contradiction with analytical expectations and current planet formation theory. Our initial investigation focuses on the evolution of a planet on an inclined orbit using three-dimensional numerical simulations. We will present these results and consider the significance of the disc structures found using synthetic observations.

Cloud Atlas: Rotational Modulations in Planetary Mass/Brown Dwarf Companions

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Time-resolved observations of rotational modulations of brown dwarfs and directly imaged exoplanets provide tight and direct constraints on the properties of condensate clouds that are a key obstacle in understanding ultra-cool atmospheres. These observations also allow precise rotation rate measurements that reveal the angular momentum evolutions of these objects. HST treasury program Cloud Atlas applies this technique to nineteen brown dwarfs and directly imaged exoplanets to evaluate the effects of temperature and surface gravity on clouds in their atmospheres. I will present the latest Cloud Atlas light curves of a few planetary mass/brown dwarf companions. We measure these companions spectral dependence of rotational modulations, especially in- and out-of-water band, and derive the vertical cloud structures in their atmospheres. We also examine the cloud property difference between these companions and field brown dwarfs. In addition, our rotation rate measurements enlarged a precious sample of low mass companions whose angular momentum can be constrained and compared to those of solar and extra-solar planets.

Dynamical Masses of Brown Dwarf Binaries as a Proxy for Testing Atmospheric and Evolutionary Models

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Atmospheric and evolutionary models are widely used to determine fundamental properties of brown dwarfs, though the reliability of these predictions is highly dependent upon the models used. Past work has shown effective temperatures and surface gravities inferred from evolutionary models do not always agree with the same parameters obtained by fitting model atmosphere spectra, and it is unclear which model the discrepancy arises from. Brown dwarf binaries with precise dynamical masses are an excellent proxy to test the predictions of these models. Spatially resolving each binary allows us to fit atmosphere model spectra to photometric and spectroscopic data of the individual brown dwarfs. With the added observational constraint on age and mass, our model comparisons provide greater potential for insight into both brown dwarf atmospheres and evolution than typically possible for isolated dwarfs. The best-fitting model spectrum results in a unique effective temperature and surface gravity independent of evolutionary model predictions. Our study involves photometric observations of 16 binary systems spanning from the optical using the Hubble Space Telescope to the near-IR using the W. M. Keck I telescope. We compare these observational data to models to further constrain effective temperatures and surface gravities for these binary systems and examine brown dwarf evolution.

INVITED REVIEW
Debris Disks and Planet Formation

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The debris disk is a distinct class of object from a protoplanetary disk. While distinguishing between them is non-trivial, especially around young stars, it is clear that the dominant physical processes through which these disks evolve are very different. Debris disks represent the longest lived phase of circumstellar disks. While debris disk enthusiasts have varying definitions for the disks, broadly they can be described as collisionally-generated disks of dust (and scant amounts of gas) around main sequence and evolved stars; these disk components must be continuously replenished through collisions of larger (usually unseen) planetesimals in the system that represent the largest components of the size distribution of objects in the disk. The presence of a debris disk is a therefore a signpost that a system underwent planet formation processes and was successful at forming planetesimal scale objects. The fact that so many observed debris disks are seen to have multiple, apparently spatially distinct, components is tantalizingly suggestive that planets are also present in many of these systems. Debris disks have been known since the era of IRAS, but they are now on a sound statistically footing, following a decade of extensive, sensitive surveys with Spitzer and Herschel, as well as wider field surveys, such as WISE. I will broadly review the demographics of the debris disk population before discussing the areas of most active research: high resolution imaging and modeling of substructures imaged in gas and dust with ALMA, the Gemini Planet Imager and SPHERE, and what these studies reveal about unseen planets. I will discuss the insights into the exozodiacal disk components that have been made in recent years, as well as the growing field of extreme debris disks, likely related to giant impacts in young systems. To close the loop on planet formation, I will explain why debris disks should not generally be regarded as the sites of planet formation, and I will discuss what debris disks can, and can not tell us, about planet formation in a given system.

Dynamical Upheaval in Ice Giant Formation

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We report on our recent theoretical work, where we suggest that a protoplanetary disk dynamical instability may have played a crucial role in determining the atmospheric size of the solar system s ice giants. In contrast to the gas giants, the intermediate-size ice giants never underwent runaway gas accretion in a full gas disk. However, as their substantial core masses are comparable to those of the gas giants, they would have gone runaway, given enough time. In the standard scenario, the ice giants stay at roughly their current size for most of the disk lifetime, undergoing period of slow gas accretion onto ~full-sized cores that formed early-on. The gas disk dissipates before the ice giants accumulate too much gas, but we believe this is fine tuned. A considerable amount of solids is observed in outer disks in mm-to-cm sized particles (pebbles). Assisted by gas drag, these pebbles rapidly accrete onto cores. This would cause the growing ice giants to exceed their current core masses, and quickly turn into gas giants. To resolve this problem, we propose that Uranus and Neptune stayed small for the bulk of the disk lifetime. They only finished their core and atmospheric growth in a short timeframe just as the disk gas dissipated, accreting most of their gas from a disk depleted to ~1% of its original mass. The ice giants have atmospheric mass fractions comparable to the disk gas-to-solid ratio of this depleted disk. This coincides with a disk dynamical upheaval onset by the depletion of gas. We propose that the cores started growing closer-in, where they were kept small by proximity to Jupiter and Saturn. As the gas cleared, the cores were kicked out by the gas giants. Then, they finished their core growth and accreted their atmospheres from the remaining, sparse gas at their current locations. We predict that the gas giants may play a key role in forming intermediate-size atmospheres in the outer disk.

The HOSTS Survey: Exo-zodiacal Dust Measurements for 30 Stars

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Warm and hot dust in the inner regions of planetary systems, near the habitable zone (HZ) and closer in, is described as being `exo-zodiacal'. The presence of large amounts of dust in the HZs of nearby stars poses a significant challenge for the target selection and planning future exo-Earth imaging missions. Our HOSTS (Hunt for Observable Signatures of Terrestrial Systems) survey on the Large Binocular Telescope Interferometer (LBTI) is designed to determine typical exozodi levels around a sample of nearby, bright main sequence stars. We use nulling interferometry in N band to suppress the bright stellar light and to detect faint, extended circumstellar dust emission. In this work we present our first statistical results from the 30 individual stars that have been observed so far. We provide important new insights into the incidence rate, typical levels, and origin of HZ dust around main sequence stars. We detect four new N band excesses in addition to the high confidence confirmation of three previous detections that allow for a detailed analyses of these systems. Among our new detections are the first three around Sun-like stars and the first two around stars without previously known circumstellar dust. Our overall detection rate is [18 (+9/-5)]%. While the detection rate is comparable for early type and Sun-like stars, it decreases from [60 (+16/-21)]% for stars with previously detected mid to far infrared excess to [9 (+10/-3)]% for stars without such excess, confirming earlier results at high confidence. For completed observations on individual stars, our sensitivity is five to ten times better than previous results. Assuming a lognormal excess luminosity function, we put upper limits on the median HZ dust level of 13 zodis (95% confidence) for all stars without cold dust and of 29 zodis when focussing on Sun-like stars without cold dust. We find first hints of a bimodal distribution where some stars have high HZ dust levels but the majority have dust levels below our sensitivity. Our results demonstrate the strength of LBTI target vetting for future exo-Earth imaging missions.

An Empirical Planetesimal Belt Radius - Stellar Luminosity Relation

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Planetesimal belts, extrasolar Kuiper belt analogues, are observed in the form of debris disks around at least ~20% of nearby Sun-like stars. Resolved dust and gas observations at millimetre wavelengths, tracing collisions between larger planetesimals, are unveiling the location and composition of these exocometary belts during the final stages of terrestrial planet formation, when volatile delivery events are most likely to take place.
In this talk, I will present a newly discovered correlation between the location (radius) of planetesimal belts in planetary systems and the luminosity of their host stars. Remarkably, our own Kuiper belt in the Solar System and CO snow lines imaged in protoplanetary disks lie close to the relation.
We carried out simulations of large belt populations which indicate that the correlation most likely cannot be explained through observational bias alone. Including steady-state collisional evolution for simulated belts better reproduces the observed trend, but produces a radius stellar luminosity relation with an intrinsic scatter that is much larger and only marginally consistent to that observed.
This relation suggests that planetesimal belts form at preferential locations in protoplanetary disks, which could be attributed to regions of enhanced planetesimal formation or inefficient growth into planets. Regardless of the process, the similarity between the observed radius stellar luminosity slope for this relation and for the CO snow lines suggests that volatility plays a crucial role in planet formation.

POSTER LOCATIONS:

First Name	Last Name	Poster Title	Number	Easel
Nicholas	Ballering	Protoplanetary Disk Masses from Radiative Transfer Modeling	100A	100
Alice	Booth	Molecular line emission from planet-hosting protoplanetary disks: sulphur monoxide as a	100B	100
James	Miley	ALMA detections of asymmetric dust and growing grains in the disc of HD100546	100C	100
Patrick	Sheehan	Constraints on Embedded Disk Masses and Structure as Seen by CARMA and ALMA	100D	100
Meredith	MacGregor	New ALMA Images of the HD 32297 and HD 61005 Debris Disks	200A	200
Raquel	Martinez	Searching for Wide-Orbit, Planetary-Mass Companions through PSF-Fitting of Spitzer/IRAC	200B	200
Anusha	Kalyaan	The Water Snow Line in Protoplanetary Disks with Different alpha profiles	200C	200
Chuhong	Mai	Proto-atmospheres Accretion on Terrestrial Planets	200D	200
Asmita	Bhandare	First core lifetime from low to high-mass star formation	300A	300
Feng	Long	ALMA survey of protoplanetary disks in Chamaeleon I and Taurus	300B	300
Rachel	Smullen	Studying Hierarchical Structure Through Time in Star Formation Simulations	300C	300
laird	close	New Results from the GAPplanetS+ Accreting Protoplanet Survey	300D	X
Logan	Pearce	Orbital motion of the long period exoplanet GSC 6214-210b	400A	400
Lisa	Prato	Astrophysics of Young Visual Binaries	400B	600
Colette	Salyk	Survey of high resolution mid-infrared water emission from protoplanetary disks	400C	600
Mengyao	Liu	The SOFIA Massive (SOMA) Star Formation Survey - Tests of Massive Star Formation Theories	500A	500
Drake	Tubbs	Modeling Protoplanetary Disks in Galactic-Metallicity Environments	500B	700
Samantha	Scibelli	Prevalent Organic Molecules towards Prestellar Cores in the Taurus Star Forming Region	500C	X
Kevin	Wagner	The Orbit of the Companion to HD 100453A: Binary Driven Spiral Arms in a Protoplanetary Disk	500D	X
Min	Li	Dust Condensation in Evolving Protoplanetary Disks	600A	600
Maria	Ubeira			
Giulia	Gabellini	The gas and dust disk around the CQ Tau protostar	600B	600
Giulia	Ballabio	Empirical diagnostics of protoplanetary disc winds	600C	600
Anna	Laws	Scattered Light Images of YSOs	600D	600
CHENG	CHEN	Formation of the Galilean satellites in a circumplanetary disk with a dead zone	700A	700
Joe	Llama	Simulating Electron Cyclotron Maser Emission for Low Mass Stars	700B	700
Jeremy	Smallwood	Disk Alignment	700C	700
Milo	Alexandra-Young	Molecular hydrogen emission from protoplanetary disk candidates in the Small Magellanic Cloud	700D	700

First Name	Last Name	Poster Title	Number	Easel
Yu	Cheng	Core mass function, kinematic and massive star formation in G286.21+0.17 revealed by ALMA	800A	800
Torsten	Loehne	Collisions In Perturbed, Eccentric Debris Disks	800B	800
Jonathan	Squire	The Disk Settling Instability: fast clumping of small grains in protoplanetary disks	800C	800
Kristina	Monsch	Dense gas kinematics and a narrow filament in the Orion A OMC1 region using NH3	800D	900
Yann	Boehler	THE COMPLEX MORPHOLOGY OF THE YOUNG DISK MWC 758: SPIRALS AND DUST CLUMPS	900A	900
Kristina	Monsch	The imprint of X-ray photoevaporation of planet-forming discs on the orbital distribution of giant	900B	900
Adam	Sutherland	Mean Motion Resonance Overlap in Migrating Circumbinary Systems	900C	900
Merel	van 't Hoff	Unveiling the physical conditions of the youngest disks: a warm disk in L1527	900D	900
Taran	Esplin	An AllWISE Survey for Circumstellar Disks in the Upper Scorpius Association	1000A	1000
Tom	Megeath	ALMA and HST imaging of Orion Protostars	1000B	1000
Ya-Lin	Wu	Low Radio Flux of Planet-mass Companions: Compact Circumplanetary Disks?	1000C	1000
Nickalas	Reynolds	Kinematics of Gravitational Unstable Disk, L1448N	1000D	1100
Pinghui	Huang	DETECTABILITY OF VORTICES IN TRANSITION DISKS	1100A	1100
Rajeeb	Sharma	Post outburst look at the chemical tracers and the protoplanetary disk around HOPS 383	1100B	1100
Megan	Holman	Radiative Transfer Models of Candidate Protoplanetary Disks in the Small Magellanic Cloud	1100C	1100
Tori	Knapp	Source multiplicity in an infrared - selected candidate protoplanetary disk in the Small	1100D	1100
Charles	Law	An SMA Continuum Survey of Circumstellar Disks in the Serpens Star-Forming Region	1300A	1300
Giovanni	Picogna	Pebble accretion in laminar and turbulent discs	1300B	1300
Kit	Lee	Eccentric and Spiral Normal Modes in Self-Gravitating Disks	1300C	1300
Ruobing	Dong	Multiple Gaps Opened by One Earth Mass Planet	1300D	2400
wei peng	lew	An unusually dusty brown dwarf's atmosphere in AB Doradus moving group	1400A	1400
Karl	Stapelfeldt	HST Imaging of Edge-on Circumstellar Disks in Nearby Star-Forming Regions	1400B	1400
Daniella	Bardalez Gagliuffi	Constraining the True Ultracool Binary Fraction via Spectral Binaries	1400C	1400
Justin	Hom	The Gemini Planet Imager View of the HD 32297 Debris Disk	1400D	X
Samuel	Factor	Kernel-Phase Interferometry for Super-Resolution Imaging of Faint Companions	1500A	1500
Daniel	Krolikowski	A Spectroscopic and Kinematic Survey of the Taurus-Auriga Star-Forming Complex	1500B	1500
Akimasa	Kataoka	Measuring the grain size in protoplanetary disks by ALMA polarization observations	1500C	2400
Rixin	Li	Properties of Planetesimals Formed by the Streaming Instability	1500D	2400

POSTER LOCATIONS:

First Name	Last Name	Poster Title	Number	Cased	
Jarron	Leisenring	JWST NIRCam Imaging of Young Planets and Disks	1600A		1600
Serena	Kim	Photoevaporating Protoplanetary Disks around a B star, 42 Orionis and Young Stellar Objects in NGC	1600B	X	
Prajkta	Mane	Timescales of Planet Formation from a Meteoritic Perspective	1600C	X	
Lauren	Biddle	K2 reveals pulsed accretion driven by the 2 Myr old hot Jupiter CI Tau b	1700A		1700
Larissa	Nofi	Preliminary Results from a Young Exoplanet RV Survey	1700B		1700
Enrico	Ragusa	Eccentricity evolution during planet-disc interaction	1700C		1700
Kendall	Sullivan	Examining Veiling and Accretion around the Young Binary Stars S Corona Australis and VV Corona	1700D		1700
Hui	Li	Dust Size Evolution in Protoplanetary Disks and Their Observable Signatures	1800A		1800
brian	mazur	Spectroscopic Survey of 400 – 1000 au Companions to Orion Young Stellar Objects	1800B		1800
Jenny	Patience	Disk Sizes and Grain Growth across the Brown Dwarf Boundary from the Taurus Boundary of	1800C	X	
Pablo	Cuartas-Restrepo	Planetary Synthesis Code – PsyCo	1900A		1900
Sierk	van Terwisga	V1094 Sco: a rare giant multi-ringed disk around a T Tauri star	1900B		1700
benedetta	veronesi	Can spirals and axisymmetric structures give us a proxy for the total disc mass? The particular case of	1900C		1700
Til	Birnstiel	Formation Scenarios and Observational Diagnostics of Dust Traps	2000A		2000
Sean	Brittain	Spectro-astrometric Survey of Warm Gas in Transition Disks	2000B		2000
Cassandra	Hall	Is the morphology of the Elias 2-27 system due to disc self-gravity?	2000C		2000
Mario	Flock	Radiation Hydrodynamical Turbulence in Protoplanetary Disks	2000D		2000
Anthony	Marston	The Distribution of Massive Stars in the Galaxy: Runaway Stars and Implications for Star Formation	2100A		2100
Alexandra	Yep	Young Stars in the Tumultuous Gum Nebula	2100B		2100
Jordan	Stone	Thermal-Infrared Observations of Planets and Protoplanets with ALES	2100C	X	
Aleksandra	Kuznetsova	How do disks inherit angular momentum?	2200A		2200
Marion	Villenave	Probing dust and gas evolution in protoplanetary disks: The pivotal Chamaeleon II association	2200B		2200
Karina	Mauco	Herschel PACS Observations of 4-10 Myr old Classical T Tauri Stars in Orion OB1	2200C	X	
Jonathan	Tan	Inside-Out Planet Formation of the Super-Earths	2600A		2600
Trent	Dupuy	The Orbital Alignment of Planets in Binaries	2600B		2600
Adam	Kraus	The Impact of Binary Companions on Planetary Systems	2600C		2600
Xianyu	Tan	ATMOSPHERIC VARIABILITY INDUCED BY RADIATIVE CLOUD FEEDBACK IN BROWN	2600D		2600

Molecular Hydrogen Emission from Protoplanetary Disk Candidates in the Small Magellanic Cloud

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We have begun a program of follow-up near infrared spectroscopy of a sample of candidate Herbig Ae/Be (HAeBe) stars in the metal-poor Small Magellanic Cloud (SMC). We have obtained K-band spectra of two targets that have UV-mm spectral energy distributions similar to those of HAeBe stars in the Milky Way galaxy. The spectra show strong emission in the ro-vibrational lines of molecular hydrogen, but no forbidden line emission nor any hydrogen recombination emission. If these are HAeBe systems then we may be observing warm gas in the inner regions of protoplanetary disks. We present a molecular hydrogen excitation analysis with estimates possible excitation mechanisms (for example thermal or fluorescent) and gas temperatures. These data will eventually be useful in a comparison of planet formation in low-metallicity environments to planet formation in the Milky Way.

Empirical Diagnostics of Protoplanetary Disc Winds

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Disc winds play an important role in the evolution of protoplanetary systems, with photo-evaporative winds in particular thought to be responsible for gas disc dispersal at late times. We present a new study of the observable diagnostics of these disc winds. We use both semi-analytic and numerical hydrodynamic models of disc winds, and compute observables such as free-free and forbidden line emission. We focus in particular on spatially-resolved observations (radio interferometry and optical/IR spectro-astrometry), and show how these techniques may allow us to measure disc mass-loss rates empirically. When combined with new observations (particularly from the VLT), these new diagnostics will allow us to build up a complete picture of how disc winds shape the evolution of planet-forming discs.
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Protoplanetary Disk Masses from Radiative Transfer Modeling

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Our goal is to measure the mass of solid material (dust) in a large sample of protoplanetary disks—a primary factor influencing the efficiency of planet formation and the properties of the resulting planetary systems. The mass of a disk is often calculated from its brightness at (sub-)mm wavelengths where thermal emission from the dust is assumed to be optically thin [1]. This procedure, however, requires choosing specific values for the dust temperature and opacity. We fit models to the full spectral energy distributions (SED) of the disks, which constrains the dust temperature and opacity and provides a more accurate measure of the disk masses. We generate model SEDs with radiative transfer simulations (using the Radmc-3d software [2]) to compute the dust temperature in a self-consistent manner and properly handle optical depth effects. We then assess the common assumptions for the dust temperature and the assumption that disks are optically thin in the sub-mm, and we quantify the effects of deviations from these assumptions on the disk masses.
Specifically, we focus on the >100 protoplanetary disks in the Taurus star-forming region with well- measured SEDs. Our fitting uses a Markov Chain Monte Carlo (MCMC) technique (implemented with the emcee software [3]) to efficiently explore a large parameter space. In addition to the disk mass, we also vary the disk size, inner edge location, scale height, flaring parameter, inclination, maximum grain size, and grain size distribution. The MCMC technique yields realistic estimates for the uncertainties and degeneracies in these parameters, which is crucial for ascertaining the statistical significance of correlations among the disk parameters and between the disk parameters (especially the disk mass) and properties of the host stars (as have been reported in the literature [4]). The disk size is not well- constrained from SED data alone, yet it has a significant influence on both the dust temperature and optical depth. Recently, spatially-resolved observations of disks have established a correlation between disk size and brightness in the sub-mm [5], and we have incorporated this correlation into our fitting criteria. Below we show a few examples of our SED fits.

Constraining the True Ultracool Binary Fraction via Spectral Binaries

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Multiplicity statistics are a direct result of the brown dwarf formation processes. Brown dwarfs are substellar objects with masses insufficient to sustain hydrogen fusion ($M < 0.08$ Msun), which harbor atmospheres that resemble those of giant planets. While star formation is fairly well understood, the essential mechanisms for brown dwarf formation are not well constrained. High resolution imaging places the brown dwarf binary fraction at 10–20%, with over 85% of systems identified in this way. The peak in the separation distribution is at 4 AU, coincidental with the resolution limit of state-of-the-art imaging techniques, suggesting that the binary fraction may be underestimated. I have developed a separation-independent method to identify and characterize binary systems of brown dwarfs as spectral binaries by identifying traces of methane in the spectra of late-M and early-L dwarfs. I compiled a volume-limited, spectroscopic sample of M7-L5 dwarfs and searched for T dwarf companions, leading to an observed spectral binary fraction of $0.79 \pm 0.11\%$, albeit for a specific combination of spectral types. To extract the true binary fraction and determine the biases of the spectral binary method, I simulated a binary population based on different assumptions of the mass function, age distribution, evolutionary models and mass ratio distribution. Applying the correction factor from the simulations to the observations yields a true binary fraction of $27 \pm 4\%$, which is roughly 1σ higher than the binary fraction obtained from high resolution imaging studies, radial velocity and astrometric monitoring. This method can be extended to identify giant planet companions to young brown dwarfs.

First Core Lifetime from Low to High-mass Star Formation

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Rolf Kuiper (University of Tübingen), Thomas Henning (Max Planck Institute for Astronomy), Christian Fendt (Max Planck Institute for Astronomy), Gabriel-Dominique Marleau (University of Bern), and Anders Kı llgan (University of Tübingen)

Topic: Star formation numerical methods

First core lifetime from low to high-mass star formation

Stars are formed by the gravitational collapse of dense, gaseous and dusty cores within magnetized molecular clouds. Understanding the complexity of the numerous physical processes involved in the very early stages of star formation requires detailed thermodynamical modeling in terms of radiation transport and phase transitions. Here, we perform core collapse simulations including the stages of first and second core formation in spherical symmetry. We use a gray treatment of radiative transfer coupled with hydrodynamics to simulate Larson s collapse. By incorporating a realistic gas equation of state via appropriate opacity tables and a density and temperature dependent adiabatic index and mean molecular weight, we model the associated phase transitions.
We investigate the properties of Larson s first and second cores and expand these collapse studies for the first time to span a wide range of initial cloud masses from 1.0 M ı to 80 M ı. Thereby, we reveal a strong dependence of the first core properties on the initial cloud mass. We find that the first core radius and mass increases with the initial cloud mass in the low-mass regime until around 10 M⊔ and decreases towards the higher masses. We also see that the lifetime of first cores strongly decreases towards the intermediate and high-mass regime.
In a nutshell, our results indicate that low-mass protostars tend to evolve through two distinct stages of formation of the first and second hydrostatic cores. In comparison, in the high-mass star formation regime, the collapsing cloud cores rush through the first core phase and essentially immediately form second Larson s core.

K2 reveals pulsed accretion driven by the 2 Myr old hot Jupiter CI Tau b

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It is challenging to detect exoplanets that orbit young stars using traditional methods of exoplanet detection. As a result, young planets are severely underrepresented within the current population of known exoplanets. This research explores a new approach to identifying signals of planetary origin around young stars and applies the technique to K2 observations of the classical T Tauri star, CI Tau, located in the Taurus star-forming region. Radial velocity observations indicate that a Jupiter-sized planet is present in the system. Periodogram analysis of the lightcurve reveals that the planet may be perturbing accretion flow onto the star, producing a modulation in brightness on the timescale of the planet's orbit.

Formation Scenarios and Observational Diagnostics of Dust Traps

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With ALMA and high-contrast optical imaging, protoplanetary disks reveal many fascinating small-scale structures. Most common among these are multiple concentric rings. These are often interpreted as being created by undetected planets opening gaps in the disk. Several people have, however, argued that these rings may also be caused by other effects. In this talk we will discuss a few possible physical mechanisms that may be responsible for the creation of these rings, how to possibly distinguish between them, and what we can learn from them.

THE COMPLEX MORPHOLOGY OF THE YOUNG DISK MWC 758: SPIRALS AND DUST CLUMPS AROUND A LARGE CAVITY

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We would like to present new Atacama Large Millimeter Array (ALMA) observations of the disk surrounding the young Herbig Ae star MWC 758, made at an angular resolution of 0.1-0.2". The data consist of images of the dust continuum emission recorded at 0.88 millimeter, as well as images of the 13CO and C18O J =3-2 emission lines.
The dust continuum emission is characterized by a large cavity of roughly 40 au in radius which might contain a mildly inner warp disk. The outer disk features two bright emission clumps at radii of < 47 and 82 au that present azimuthal extensions and form a double-ring structure. The comparison with radiative transfer models indicates that these two maxima of emission correspond to local increases in the dust surface density of about a factor 2.5 and 6.5 for the south and north clump, respectively. The optically thick 13CO peak emission, which traces the temperature, and the dust continuum emission, which probes the disk midplane, additionally reveal two spirals previously detected in near-IR at the disk surface. The spirals seen in the dust continuum emission present however a slight shift of a few au towards larger radii and one of the spirals crosses the south dust clump. Finally, we will propose different scenarios, implying planets, able to explain the complex structure of the disk."

Molecular line emission from planet-hosting protoplanetary disks: sulphur monoxide as a potential tracer of a molecular disk wind?

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Spatially resolved ALMA observations of the (sub-)millimetre-sized dust grains and molecular gas in protoplanetary disks are providing an incredible insight into the processes under which disks evolve and planets form. Protoplanetary disks around Herbig Ae/Be are excellent targets for observation since nearby sources subtend a larger angular scale in the sky and are brighter than their T Tauri counterparts making it easier to resolve their structures. In addition, these systems are thought to be the precursors for exoplanets detected via direct imaging. In this talk I will present new detections of simple volatiles in the protoplanetary disks around HD100546 and HD97048 using ALMA. Both disks exhibit ring structures in their sub-mm dust emission. However, only the HD100546 disk exhibits direct evidence for a forming planet / massive companion. We have detected three rotational transitions of sulphur monoxide (SO) in this disk: prior to this work SO has only been spatially resolved in one other disk, AB Aur. I will discuss the possible process(es) that the SO emission is tracing and the detections of other molecules in the HD97048 disk which trace alternative processes.

Spectro-astrometric Survey of Warm Gas in Transition Disks

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In this poster we will present results of our ongoing spectro-astrometric survey of warm gas in transition disks using iSHELL on the IRTF. We will discuss the utility and limits of using a 3m telescope for spectro-astrometry and compare the performance of iSHELL relative to other NIR echelle spectrographs. We will also compare the line profiles of the newly acquired observations to previously published results spanning baselines of up to 15 years and highlight how such observations can be used to identify forming gas giant planets in disks.

Formation of the Galilean satellites in a circumplanetary disk with a dead zone

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The prograde, nearly circular and nearly coplanar orbits of the Galilean satellites suggest that they formed in a circumplanetary disk. With the grid-based hydrodynamic code, FARGO3D, we simulate a disk with a dead zone, a region of low turbulence where the magnetorotational instability (MRI) does not operate because of the low temperature and high surface density. The dead zone provides a cold environment for icy satellite formation. Tidal torques from the sun constrain the size of the circumplanetary disk to be about 0.4 R_H. We explore possible disk parameters that provide a suitable environment for satellite formation.

Core mass function, kinematic and massive star formation in G286.21+0.17 revealed by ALMA

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G286.21+0.17 is a massive protocluster at a distance of 2.5 kpc. We have mapped a field of 5.3 ι.5.3 towards G286 with the Atacama Large Millimeter/submillimeter Array(ALMA) in band 6(1.3mm) at a resolution of 1.0   (2500AU). We measure the core mass function (CMF) with continuum emission in the central region, exploring various core detection algorithms, which give source number ranging from 60 to 125, depending on parameter selection. For masses M s 1 M.J, the fiducial dendrogram-identified CMF can be fit with a power law of the form dN/dlogM M∟ with ı C 1.24 ┌ 0.17, consistent with the index of the Salpeter stellar initial mass function of 1.35. Deuterated species N2D+ is detected in about one third of the core sample and all these cores are distributed in the outer region of the cluster, possibly tracing new generation star formation triggered by feedback. The velocity dispersion of different cores, measured with N2D+ and C18O, is about 1.52km/s, larger than that required for virial equilibrium (~1.04km/s). The molecular outflow in this region is dominated by a large scale (~0.5pc) wide- angle bipolar component, which is driven by the central brightest core of G286. Interestingly, extra uv coverage during an antenna configuration transition in observation has given us a glimpse into small substructures of this massive core (~65Msun). We managed to map it with a large dynamic range of resolutions from down to 0.0522, corresponding to 125AU in linear resolution. The core exhibits clear hierarchical fragmentation at different scales. In the 0.1222 resolution map, the core is clearly resolved into a binary system separated by about 600AU, along with multiple weak condensations nearby. With the highest resolution available (~0.0522), one of the binary component exhibits even further fragmentation at the scale of 150AU. Our observation reveals e a multiple protostellar system of YSOs at the center of a protocluster with at least intermediate mass, and potentially able to form massive stars. We discuss the implications of these results for star and star cluster formation theories.

New Results from the GAPplanetS+ Accreting Protoplanet Survey

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We report of the latest findings of our survey of all southern transitional disks with high-contrast imaging at H-alpha..We have confirmed the accreting planets previously imaged by MagAO in Sallum et al. 2015 (Nature 527, 342). We have now fully commissioned the new "non-polarizing" Simultaneous Differential Imaging mode (SDI+). This new mode enables a 300% improvement of high contrast imaging at Halpha (0.65 microns) with the 6.5m Magellan Adaptive optics System (MagAO). We will highlight how SDI+ has allowed a clearer view of the first protoplanets in the LkCa 15 system. We will review the status of the survey and results to date, and how this helps us understand how giant planets really form.

Planetary Synthesis Code PsyCo

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Based on the works of Ida & Lin (2004, 2008), Mordasini et.al (2009), as well as the works of Beauge & Aarseth (1990) and Raymond et.al (2009), we have developed a code in python that synthesizes planetary systems. The code models the evolution of the gas and dust components of the protoplanetary disk, as well as the dynamical evolution including migration around young stellar objects of different masses. This code allows us to model the initial accretion of planetary embryos, as well as the formation of giant nuclei and gas accretion. At the end of the accretion, the code allows us to model the gravitational interaction of the N-bodies until the establishment of a planetary system.

Multiple Gaps Opened by One Earth Mass Planet

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Recently ALMA observations have identified multiple narrow gaps and rings as the most common type of features in protoplanetary disks. One hypotheses is that these gaps and rings are produced by planets. While in the conventional picture, one planet produces only one gap by planet-disk interaction, the ubiquity of multiple gaps in disks promotes the exploration of alternative gap opening scenario. We have found that in low viscosity disks, a low mass planet, Earth-to-Neptune mass, can produce multiple narrow gaps in mm-sized dust. These gaps can have a huge variety in morphology, such as spacing, width, depth, and total number. Their morphology depends on a variety of parameters, such as the disk scale height, its gradient, planet mass, and the length of the evolution. I will introduce recent progresses in opening multiple gaps by one low mass planet, and make connections with ALMA observations.

The Orbital Alignment of Planets in Binaries

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Most planetary systems only offer the possibility to measure either the initial conditions of planet formation (e.g., protoplanetary disks) or the final outcome (e.g., demographics of field samples). Planet-hosting binaries offer the rare opportunity to observe both simultaneously. We will present results from our Keck adaptive optics program to monitor the stellar orbits of Kepler planet hosts that have binary companions at solar-system scales of 20-200 AU. The astrometric orbital arcs that we measure enable a fundamental test: whether or not the stellar orbits are seen edge-on and thus co-aligned with the transiting planets in the system. This orbit-orbit alignment test allows us to critically examine the possible formation pathways for these systems. We also discuss preliminary results for a subset of our sample for which we have obtained resolved radial velocities with NIRSPAO that allow us to determine additional orbit parameters (eccentricity and semimajor axis). Full orbit determinations will allow us to address whether special conditions, e.g., circular orbits, are needed to promote planet formation in binary systems, perhaps explaining why the systems in our sample survived in the first place while close stellar companions seem to suppress planet formation in most other comparable binary systems.

An AllWISE Survey for Circumstellar Disks in the Upper Scorpius Association

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Because it contains one of the richest and nearest populations of young stars (d = 125-165 pc, N ~ 1000) and is at an age where both primordial circumstellar disks and second-generation debris disks are abundant, the Upper Scorpius association is one of the most valuable laboratories for studying disk evolution. To facilitate such studies, we have used the mid-IR photometry from the AllWISE survey performed by the Wide-field Infrared Survey Explorer (WISE; 3.4, 4.6, 12, and 22 microns) to search for new disk-bearing members of Upper Scorpius. Candidates were identified by their red IR colors and were further refined using ancillary data. Through spectroscopy, we confirmed 215 new disk-bearing objects, 81 of which host disks that are in an advanced stage of evolution.

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

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Direct detection of close in companions (exoplanets or binary systems) is notoriously difficult. While coronagraphs and point spread function (PSF) subtraction can be used to dig out signals of companions under the PSF, there are still significant limitations in separation and contrast. Non-redundant aperture masking interferometry (NRM or AMI) can be used to detect companions well inside the PSF of a diffraction limited image, though the technique is severely flux limited since the mask discards ~95% of the light gathered by the telescope. Kernel-phase analysis applies interferometric techniques similar to NRM to an unobscured diffraction limited image. Instead of non-redundant closure-phases, kernel-phases are constructed by simulating a redundant interferometer with a grid of points covering the full telescope aperture. I have developed a new faint companion detection pipeline which analyzes kernel-phases utilizing Bayesian model comparison. I demonstrate this pipeline on archival HST/NICMOS images of nearby brown dwarfs, refining astrometry of previously known companions and searching for new companions in order to constrain binary formation models at separations inaccessible to previous techniques. Using this method, it is possible to detect a companion well within the classical l/D diffraction limit using a fraction of the telescope time as NRM. Since JWST will be able to perform NRM and full frame imaging, further development and characterization of kernel-phase analysis will allow efficient use of highly competitive JWST telescope time. In the near future, I will use this technique to search for planetary mass companions using HST observations of young star forming regions.

Radiation Hydrodynamical Turbulence in Protoplanetary Disks

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Planets are born in protostellar disks, which are now observed with enough resolution to address questions about internal gas flows. We report new results from high-resolution global 3D radiation-hydrodynamics simulations with embedded particles.

The vertical shear instability (VSI) develops into a steady state turbulence resulting into turbulent speeds of a few percent of the local sound speed at the midplane, increasing to 20%, or 100 m s−1 , in the corona. These are consistent with recent upper limits on turbulent speeds from optically thin and thick molecular line observations of TW Hya and HD 163296. The predominantly vertical motions induced by the VSI efficiently lift particles upward. Grains 0.1 and 1 mm in size achieve scale heights greater than expected in isotropic turbulence. We conclude that while kinematic constraints from molecular line emission do not directly discriminate between magnetic and nonmagnetic disk models, the small dust scale heights measured in HL Tau and HD 163296 favor turbulent magnetic models.

Is the morphology of the Elias 2-27 system due to disc self-gravity?

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A recent ALMA observation of the Elias 2-27 system revealed a two-armed structure extending out to ¬300 au in radius. The protostellar disc surrounding the central star is unusually massive, raising the possibility that the system is gravitationally unstable. Recent work has shown that the observed morphology of the system can be explained by disc self-gravity, so we examine the physical properties of the disc necessary to detect self-gravitating spiral waves. Using three-dimensional Smoothed Particle Hydrodynamics, coupled with radiative transfer and synthetic ALMA imaging, we find that observable spiral structure can only be explained by self-gravity if the disc has a low opacity (and therefore efficient cooling), and is minimally supported by external irradiation. This corresponds to a very narrow region of parameter space, suggesting that, although it is possible for the spiral structure to be due to disc self-gravity, other explanations, such as an external perturbation, may be preferred.

Radiative Transfer Models of Candidate Protoplanetary Disks in the Small Magellanic Cloud

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Using spectra models with known parameters and comparing them to spectra gathered from real systems is often the only ways to determine what is going on in those real systems. This project uses the modeling programs of RADMC-3D to generate model spectra for systems containing protoplanetary disks. We are working on producing a grid of models that all have different variations in the parameters in order to generate a miniature database to use for comparisons to gathered spectra. The spectra produced from these simulations will be compared to spectra that have been gathered from systems in the Small Magellanic Cloud in order to find out the contents, including types of dust, and the presence of gaps and flaring, and the stage of development of that system. This will enable us to examine the early stages of planet formation around stars in the Small Magellanic Cloud, a nearby, metal-poor galaxy relative to the Milky Way galaxy.

The Gemini Planet Imager View of the HD 32297 Debris Disk

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Joseph Zalesky (School of Earth and Space Exploration, Arizona State University)
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Max Millar-Blanchaer (Jet Propulsion Laboratory)
Thomas M. Esposito (Department of Astronomy, University of California, Berkeley)
Pauline Arriaga (Department of Physics and Astronomy, University of California, Los Angeles)
Michael P. Fitzgerald (Department of Physics and Astronomy, University of California, Los Angeles)
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The GPIES Team (Various Institutions)
Topic: Debris Disk Characterization
The Gemini Planet Imager View of the HD 32297 Debris Disk

The HD 32297 debris disk system consists of a young (<30Myr) A-star surrounded by both a dust disk resolved at near-IR to mm wavelengths and a gas disk detection. In previous observations, the nearly edge-on geometry has been traced over size scales from ~50 AU to 100 s of AU with scattered light, thermal imaging and mm mapping with several indications that the disk is not axisymmetric. Extreme adaptive optics imaging from the ground enables the highest spatial resolution and highest contrast imaging of the scattered light component of the disk, and we present Gemini Planet Imager (GPI) H-band total intensity and polarized intensity imaging to investigate the disk structure. Previous studies have suggested complex radial structures such as double rings, but there is uncertainty about the nature of this result due to the possibility of artifacts introduced in the PSF subtraction routine. To address this important structural question of the presence or absence of a disk gap, the GPI H-band data were processed with three independent techniques the standard pyKLIP algorithm used in the GPIES planet search, the RDI (Reference Differential Imaging) PSF-subtraction routine developed for GPI data, and a mask-and-interpolate procedure. Based on the initial results of the study, ADI reductions produced a gapped structure on the NE side of the disk, but both the RDI and mask-and-interpolate procedures do not produce a gap in surface brightness. An initial polarization fraction map of the disk is also created. The bright, edge-on nature of the disk makes it a prime target for upcoming JWST observations and has already been approved.

DETECTABILITY OF VORTICES IN TRANSITION DISKS

Pinghui Huang, Purple Mountain Observatory
Andrea Isella, Rice University
Hui Li, Los Alamos National Laboratory

Topic: Transition disk, Vortex

DETECTABILITY OF VORTICES IN TRANSITION DISKS

There are many transitional disks that have been observed to display significant azimuthal asymmetries in dust continuum, such as IRS 48, LkHα 330, HD 142527, etc. We investigate the influence of a massive planet in producing such asymmetries by carrying out 2D hydrodynamic simulations and 3D radiative transfer calculation. Our primary goal is to determine the detectability of vortices in both gas and dust emissions, find out the factors which affect the feature of vortex. By using CASA(Common Astronomy Software Applications package), we generate the synthetic ALMA images of dust continuum and gas moment maps. We find that the signatures of vortices in our simulated models can be detectable in certain ALMA configurations. Using IRS 48 disk as an example, we quantify the vortex signatures and describe the required ALMA configurations.

The Water Snow Line in Protoplanetary Disks with Different Alpha Profiles

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The water snow line, i.e., the region in the disk that demarcates where water in the solar nebula is in the form of vapor, and where it freezes out as ice, is critical for planet formation [1]. It not only determines the location of formation of gas-giant planets, it also determines the bulk water content of planets that formed inside or outside of the snowline [2][3][4]. The balance of radial transport processes of volatiles across the snowline such as diffusion of water vapor and inward flux of icy particles determines the radial distribution of water in the disk [5][6], but these processes are themselves strongly influenced by several factors, such as: local temperature-pressure conditions in the disk and local turbulent viscosity, and still others such as an accreting proto-planet beyond the snowline, that might be able to entrap drifting ices [7], or even photoevaporation. In this work, we build on [8] and explore the effect of variation of turbulent viscosity across the snowline using three different α profiles inspired from the MRI [8] and cosmochemical constraints [9]. As α is able to influence mass flow, temperature as well as diffusion of small icy particles, we find that the gradient of α across the snowline is imperative to consider in disk evolution models to retrace the distribution of water in the solar nebula.
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Measuring the grain size in protoplanetary disks by ALMA polarization observations

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Constraining the grain size in protoplanetary disks is a key to understanding the first stage of planet formation. The grain size has been estimated by measuring the spectral index at millimeter wavelengths, while it has huge uncertainties. We propose an alternative way to constrain the grain size using millimeter-wave polarization. We show that thermal dust emission is scattered off of other dust grains, which produces millimeter-wave polarization with a fraction of ~2.5 %. By performing multi-wave polarization observations, we can constrain the grain size because the polarization is the most efficient when the grain size is comparable to the wavelengths. We also report two ALMA polarization observations of protoplanetary disks toward HD142527 and HL Tau. We detect the polarized emissions in both cases. In the case of HD 142527, we confirm that the self-scattering is working by morphological discussions. In the case of HL Tau, the polarization pattern at 3.1 mm is completely different from that at 1.3 mm. We interpret that the strong wavelength dependence is due to the self-scattering. By modeling the polarized emission, we constrain the grain size to be 70 micron.

Photoevaporating Protoplanetary Disks around a B star, 42 Orionis and Young Stellar Objects in NGC 1977 a Sibling of the Orion Nebula Cluster

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We present the discovery of photoevaporating protoplanetary disks (proplyds) around a B1 star in NGC 1977, a sibling star-forming region of the Orion Nebula Cluster (ONC). NGC 1977 is located at about half a degree north of the ONC at a distance of about 400 parsec, similar to the ONC, but it lacks high mass O stars unlike in ONC. Nevertheless, we have identified seven proplyds in vicinity of its most massive star, 42 Ori (B1V). These proplyds show cometary H alpha emission in HST ACS images, with clear ionization front and tails evaporating away from a B1 star. These are the first proplyds to be found around a B star, while all previously known proplyds are found in vicinity of O stars. The FUV radiation field impinging on these proplyds is 10-30 times weaker than that on the proplyds in ONC. We find that observed proplyd sizes are consistent with models for FUV photoevaporation in weak FUV radiation. Three of the proplyds are potentially very low mass sub-stellar objects. We also discuss our recent work on a very low mass substellar object (M9.5), which is also a proplyd, located in the ONC. We discuss properties of stars, ages, and kinematics of the young stellar objects in NGC 1977, and compare them to its sibling, ONC, and to other YSO populations in Orion A.

Source multiplicity in an infrared - selected candidate protoplanetary disk in the Small Magellanic Cloud

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Topic: Protoplanetary Disks
Source multiplicity in an infrared-selected candidate protoplanetary disk in the Small Magellanic Cloud

In our study of low metallicity protoplanetary disks evolution among candidate Herbig Ae/Be stars in the Small Magellanic Cloud, we have identified an infrared bright object that upon investigation with HST has shown to be a source of >10 individual objects. Using BVRI photometry we have begun to characterize the nine brightest objects in order to determine which source(s) are responsible for the infrared point source emission. We will use the results of this analysis to motivate follow-up spectroscopic observations of our candidate Herbig Ae/Be stars with higher spatial resolution (e.g. JWST) to more precisely co-locate the observed IR excess with the optical sources.

The Impact of Binary Companions on Planetary Systems

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The majority of solar-type stars are found in binary systems, and the dynamical influence of binary companions is expected to profoundly influence planetary systems. However, the difficulty of identifying planets in binary systems has left the magnitude of this effect uncertain; despite numerous theoretical hurdles to their formation and survival, at least some binary systems clearly host planets. We present high-resolution imaging of nearly 500 Kepler Objects of Interest (KOIs) obtained using adaptive-optics imaging and nonredundant aperture-mask interferometry on the Keck II telescope. We super-resolve some binary systems to projected separations of under 5 AU, showing that planets might form in these dynamically active environments. However, the full distribution of projected separations for our planet-host sample more broadly reveals a deep paucity of binary companions at solar-system scales. Our results demonstrate that a fifth of all solar-type stars in the Milky Way are disallowed from hosting planetary systems due to the influence of a binary companion. We now update these results with multi-epoch imaging to reject non-comoving background stars and securely identify even the least massive stellar companions, as well as tracing out the orbital motion of stellar companions. These results are beginning to reveal not just the fraction of binaries that do not host planets, but also potential explanations for planet survival even in some very close, dynamically active binary systems.

A Spectroscopic and Kinematic Survey of the Taurus-Auriga Star-Forming Complex

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The Taurus-Auriga star-forming complex is one of the most comprehensively studied regions of star-formation in the Milky Way. The census of Taurus members has been built over the last eighty years, but questions remain as to its completeness. In particular, the discovery of a distributed stellar population at large distance from the central molecular clouds and ongoing star formation has further drawn into question the completeness of the census and Taurus' star formation history. We have obtained spectra of hundreds of Taurus candidate members using the Tull coudé spectrograph on the 2.7m Harlan J. Smith telescope at McDonald Observatory in order to address the above questions of census completion. We have derived youth indicators and radial velocities to refine membership, and establish infrastructure for complete 3D kinematic analysis once Gaia DR2 proper motions and parallaxes are released. We will present a census of Taurus updated with confirmation of previously known candidate members and identification of new member stars. We plan to implement new methods to analyze the spatial and kinematic distributions of different age subpopulations in Taurus. Future directions for this project include the expansion of our analysis to other stellar associations and star-forming regions, and exoplanetary searches using a variety of ground-based and space observation techniques.

How do disks inherit angular momentum?

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Circumstellar disks play an all important role in star and planet formation, dictating the appearance of young stellar objects and setting the environment in which planets are born. Understanding the range and frequency of disk properties is crucial for contextualizing current observations of disks and motivating the future of planet formation theories. As much of star formation occurs on swift dynamical timescales spanning several orders of magnitude of spatial scales, we perform top-down large scale numerical simulations starting from the star cluster scale extending down to the protostellar envelope to obtain a set of physically motivated initial conditions for the formation of circumstellar disks. We report on the results of a suite of simulations done with the MHD code Athena investigating the relative range and distribution of angular momenta and other initial conditions in protostars and their envelopes using a new sink-patch algorithm. We compute the evolution of angular momenta in these objects, compare our results to analytic models of rotating collapse, and comment on the physical assumptions behind protostellar core formation.

An SMA Continuum Survey of Circumstellar Disks in the Serpens Star-Forming Region

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We present observations with the Submillimeter Array of the continuum emission at = 1.3 mm from 62 young stars surrounded by a protoplanetary disk in the Serpens star-forming region. The typical angular resolution for the survey in terms of beam size is 3.522 r 2.522 with a median rms noise level of 1.6 mJy beam-1. These data are used to infer the dust content in disks around low-mass stars (0.12.5 M) at a median stellar age of 13 Myr. Thirteen sources were detected in the 1.3 mm dust continuum with inferred dust masses of H10260 M and an upper limit to the median dust mass of 5.1 (+6.1 / -4.3) M, derived using survival analysis. Comparing the protoplanetary disk population in Serpens to those of other nearby star-forming regions, we find that the populations of dust disks in Serpens and Taurus, which have a similar age, are statistically indistinguishable. This is potentially surprising since Serpens has a stellar surface density two orders of magnitude in excess of Taurus. Hence, we find no evidence that dust disks in Serpens have been dispersed as a result of more frequent and/or stronger tidal interactions due its elevated stellar density. We also report that the fraction of Serpens disks with Mdust e 10 M is less than 20%, which supports the notion that the formation of giant planets is likely inherently rare or has substantially progressed by a few Myrs.

Scattered Light Images of YSOs

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We present scattered light images of disks around YSOs obtained using the Gemini Planet Imager (GPI) instrument at the Gemini South Observatory. These results are from the first two observing runs of our Long and Large Program (Scattered Light imaging of YSOs: Probing the Fundamental Stages of Planet Formation) which targets stars likely to be YSOs and harbor disks. The images were taken at J- and H-bands using the coronographic mode of GPI with adaptive optics and Differential Polarimetric Imaging (DPI), achieving high-resolution images of the light scattered from circumstellar material. We observe a variety of scattered light morphologies, including gaps, spiral structures, and hourglass nebulae. We also present some preliminary radiative transfer models for a subset of the objects.

Eccentric and Spiral Normal Modes in Self-Gravitating Disks

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Depending on the disk mass, typical protoplanetary disks can support stable eccentric modes ($m=1$) or unstable global spiral modes of higher m. We report some new results on the normal modes in a gas disk, based on the spiral density wave theory.
For a low-mass disk with Toomre Q parameter tens or larger, the eccentric modes precess slowly and decay over long viscous time scale. The relevant parameter to characterize the waves is given by $g = 1/(Q\,h)$, where h is the disk aspect ratio. When $g < 1$, the disk is pressure-dominated and supports mainly retrograde pressure modes. When $g > 1$, the disk supports gravity-dominated prograde modes, which have complex wave cycles involving both long and short waves. Because of the presence of turning points, some of the modes are trapped in the disk and do not feel the disk edge. As a result, these eccentric modes can be long-lived in the disk. For a massive disk with Q close to but bigger than unity, the waves experience over-reflection at the corotation and get amplified. Hence, these unstable global spiral modes may be responsible to the grand-design bisymmetric spirals in protoplanetary disks observed by ALMA.

JWST NIRCam Imaging of Young Planets and Disks

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The James Webb Space Telescope (JWST) offers many advantages over ground-based observations at >3 m where exoplanets emit most strongly, providing favorable contrast relative to their host star. This study primarily employs NIRCam's long-wave module (2.5 5.3 ¬m) to characterize exoplanet atmosphere in various filter bandpasses and probe the structure and composition of young debris disks. Our aim is to characterize known exoplanets and disks while also searching for additional companions only accessible to JWST's unprecedented sensitivity and wavelength coverage. Deep imaging of these young systems can provide a snapshot of planets at the site of their formation, prior to orbital evolution, and place constraints on their occurrence, formation, and evolution. MIRI observations will complement those of NIRCam, measuring the thermal component of disks while also determining the effective temperature and luminosity of detected exoplanets. Observations with NIRISS can further utilize non-redundant masking (NRM) to probe closer to the parent star than is possible with NIRCam imaging.

An unusually dusty brown dwarf's atmosphere in AB Doradus moving group

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Large-scale infrared parallax survey reveals that young brown dwarfs (<150 Myrs) show dramatic reddening compare to the field brown dwarfs. The observed red color (e.g, J-Ks) is often related to the dusty atmosphere, which has been suggested to be caused by enhanced metallicity, low gravity or chemistry disequilibrium. In HST Cloud Atlas survey (PI: Daniel Apai), we have discovered that WISEP J0047, an unusually red L7 dwarf in AB Doradus moving group, has the largest ever-observed rotational modulation amplitude among L dwarfs. I will show that how this dusty atmosphere can be explained with a self-consistent cloud model and discuss its implication on the perturbed cloud pressure level and the corresponding condensate properties. Lastly, I will compare the variability amplitudes and rotation periods among currently known young red L dwarfs.

Properties of Planetesimals Formed by the Streaming Instability

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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. In this talk, I will present a further diagnosis of the properties of those bound clumps produced in our simulations. We have developed a new clump-finding tool to more 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. We then use this tool to investigate the mass and angular momentum distributions within each clump. We report that massive planetesimals tend to be more prograde and more concentrated in their very central region. Additionally, 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.

Dust Size Evolution in Protoplanetary Disks and Their Observable Signatures

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We investigate the effects of dust grain size evolution in protoplanetary disks (PPDs) using high resolution gas+dust two-fluid hydrodynamics simulations, along with the self-consistently dynamic dust coagulation and fragmentation processes. Specifically, we examine how dust particles will accumulate in certain regions of the disk due to various effects such as planet-disk interactions and variable disk viscosity. Such accumulation will promote grain size evolution, leading to signatures in the observed images and spectral properties of PPDs. Observables are obtained via radiative transfer processing of the simulated disks. We present these results and compare them with multi-frequency observations. Effects of optical depth, total disk gas and dust masses, and implications for protoplanet formation will be discussed as well.

Dust Condensation in Evolving Protoplanetary Disks

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Partial condensation of the Solar nebula is thought to be responsible for the diverse chemical compositions in the rocky planets/planetesimals in the inner Solar system. Here we present a forward physical-chemical model to study the chemical evolution of a protoplanetary disk, and the chemical compositions of possible planetesimals that may form. We will model the evolution of protoplanetary disks with different initial conditions and the condensation of the dust within those disks. We give the time evolution of the abundance of elements in gas and dust at different radii for different disks and show how the change of the chemical abundances may affect the planet formation process. We expect to put some constraints on the chemical compositions of some rocky exoplanets.

The SOFIA Massive (SOMA) Star Formation Survey - Tests of Massive Star Formation Theories

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We present an overview and latest results of the SOFIA Massive (SOMA) star formation survey, which aims to build up a sample of ~ 50 massive and intermediate-mass protostars in a range of different environments that are observed across MIR and FIR bands to test theoretical models of massive star formation. We present multi-wavelength images which reveal outflow cavities and characteristic extinction patterns, and build the spectral energy distributions (SEDs) of massive and intermediate-mass protostars observed with SOFIA-FORCAST from ~ 10 to 40 μm together with archival Spitzer and Herschel data and other ground-based IR data. Radiation transfer (RT) models of Zhang & Tan 2018, which are based on the Core Accretion scenario, including outflow cavities driven by MHD disk winds, are then fit to the SEDs and yield key properties of the protostars. We also discuss HST and ALMA follow-up of the sources.

Simulating Electron Cyclotron Maser Emission for Low Mass Stars

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Zeeman-Doppler Imaging (ZDI) is a powerful technique that enables us to map the large-scale magnetic fields of stars spanning the pre- and main-sequence. Coupling these magnetic maps with field extrapolation methods allow us to investigate the topology of the closed, X-ray bright corona, and the cooler, open stellar wind. Using ZDI maps of young M dwarfs with simultaneous radio light curves obtained from the VLA, we present the first results of modeling the Electron-Cyclotron Maser (ECM) emission from these systems. We determine the X-ray luminosity and ECM emission that is produced using the ZDI maps and our field extrapolation model. We compare these findings with the observed radio light curves of these stars, allowing us to predict the relative phasing and amplitude of the stellar X-ray and radio light curves. This benchmarking of our model using these systems allows us to predict the ECM emission for some 80 stars that have a ZDI map and an observed X-ray luminosity. Our model allows us to understand the origin of transient radio emission observations and is crucial for disentangling stellar and exoplanetary radio signals.

Collisions in Perturbed, Eccentric Debris Disks

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High-resolution images of circumstellar debris discs reveal off-centred rings that indicate past or ongoing perturbation, possibly caused by secular gravitational interaction with unseen stellar or substellar companions. The purely dynamical aspects of this departure from radial symmetry are well understood. However, the observed dust is subject to additional forces and effects, most notably collisions and drag.
With an improved version of our numerical code ACE, we therefore studied a set of fiducial discs with global eccentricities. Resulting size and spatial distributions of dust are analysed and interpreted. We show the basic impacts of secular perturbation and belt eccentricity on spectral energy distributions and images.
While radiation pressure alone produces asymmetries in the belt and the halo of small grains, collisional evolution tends to weaken these asymmetries. Ongoing differential secular precession results in a misalignment of belt and halo.

ALMA survey of protoplanetary disks in Chamaeleon I and Taurus

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Masses of protoplanetary disks limit the formation and future growth of any planet. We use ALMA to survey 887um emission and CO isotopologue line emission in a near complete sample of protoplanetary disks in the 2 Myr Chamaeleon I star-forming region, to measure the disk dust mass and gas mass simultaneously. The dust emission, detected from 66 of 93 sources, led to an Mstar Mdisk relation with the power-law index of 1.31.9. In this talk, we will discuss deeper, follow-up observations of the undetected and marginally-detected disks. We will also discuss the low detection rate of 13CO (17 sources) and C18O (1 source) in this survey. We calculate gas mass by comparing CO line luminosity to chemical model grids which include CO freeze-out and isotope-selective photodissociation. Under the assumption of a typical ISM CO-to-H2 ratios of 10^-4, the resulting gas masses are implausibly low, with an average gas mass less than 0.1 Mjup. The faint CO line emission may instead be explained if disks have much higher gas masses, but freeze-out of CO or complex C-bearing molecules is underestimated in disk models. Finally, I will report preliminary results about disk structures from 33 disks in Taurus star-forming region.

New ALMA Images of the HD 32297 and HD 61005 Debris Disks

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HD 61005 (G-type star, The Moth) and HD 32297 (A-type star) host two of the most iconic debris disks. Scattered light images show that both disks are nearly edge-on with dramatic swept-back wings of dust. Previous studies have proposed a range of mechanisms to explain this distinctive morphology including interactions with the interstellar medium, secular perturbations of grains by low-density, neutral interstellar gas, and gravitational interactions with an inclined, eccentric companion. We present new observations from the Atacama Large Millimeter/submillimeter Array (ALMA) at 1.3 mm that provide the highest resolution images at millimeter wavelengths to date of both systems. Observations at millimeter wavelengths are especially critical to our understanding of the physical mechanisms shaping the structure of these disks, since the large grains that dominate emission at these wavelengths are less affected by stellar radiation and winds and more reliably trace the underlying planetesimal distribution. We fit models directly to the observed visibilities within a Markov Chain Monte Carlo (MCMC) framework to characterize the continuum emission and place constraints on the structure of these unique debris disks. Our new ALMA images reveal that despite differences in spectral type, both systems are best described by a two-component structure with (1) a parent body belt, and (2) an outer halo aligned with the scattered light disk. Such halos have typically been assumed to be composed of small grains visible in scattered light, so these images are some of the first observational evidence that larger grains may also populate extended halos. In addition, we detect significant 12CO gas emission from HD 32297, and determine a robust upper limit for HD 61005.

Proto-atmospheres Accretion on Terrestrial Planets

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Protoplanets are believed to form before gas dissipates in the stellar nebula and thus they are likely to capture proto-atmospheres from the nebula gas. Such hydrogen/helium-rich atmospheres have been detected and characterized in exoplanetary systems (e.g. low-density super Earths and mini Neptunes). The accretion and structure of the proto-atmosphere is subject to the evolution of the protoplanetary disk such as the evaporation of nebula gas, the XUV radiation from the central star, the potential impacts between planetoids, the shape of the protoplanet s orbit and the protoplanet mass. We have been using the hydrodynamics code Boxzy Hydro to simulate the gravitational accretion of gas onto a protoplanet and its subsequent evolution. We first establish a one-dimensional stationary model assuming spherical symmertry and constant accretion luminosity (due to planetesimal impacts) to benchmark the results with Stokl et al. (2015) which used a different numerical approach. I will introduce the series of work in progress and in plan to model the proto-atmosphere accretion in a more physically realistic sense, including implementing sophisticated treatments of planetesimal accretion rate, planet mass and atmosphere opacities, and exploring the influence from the planet traveling on an eccentric orbit.

Modeling the accretion of proto-atmospheres is essential to many scientific topics, including the nebula origin of Earth s water and other volatiles (H2, CO/CO2, N2, etc.), the supply of Earth s noble gases and the role of proto-atmospheres in chondrule-forming planetary bow shocks. Understanding how the proto-atmospheres could influence or even create the current terrestrial planetary environments in the solar system also has general significance to the study of exoplanet habitability.

Timescales of Planet Formation from a Meteoritic Perspective

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We will discuss a review of radiometric dating of various meteoritic components to understand the timescales over which the planetary-formation processes in our solar system operated and to compare them with planet formation from astrophysical perspective. The age of our solar system is defined by Pb-Pb dating of the Calcium-Aluminum-rich Inclusions (CAIs) from primitive meteorites as 4567.30 0.16 Ma. Most refractory inclusions formed in a short time period of ~ 20,000 years, but chondrules (other major components of chondritic meteorites) continued to form for ~ 4 Ma after CAI-formation. Radiometric dating of differentiated meteorites suggests that planetesimal accretion and differentiation occurred early, beginning within ~1 Ma of the formation of the earliest-formed solids in the solar system. Isotopic evidence suggests that Mars accreted ~50% of its current mass within the first ~2 Ma of CAI formation and Jupiter's core grew to 20 earth masses within ~1 Ma and up to 50 earth masses within ~3-4 Ma following CAI formation. These data collectively suggest that planetesimal accretion occurred quickly and that planetary embryos (i.e., at least half the size of Mars and possibly larger) existed while smaller solids, like chondrules and CAIs, were being processed in the solar nebula. Therefore, while accretion for differentiated parent bodies was a relatively quick process, chondritic parent bodies took ~2-5 Ma to accrete.

The Distribution of Massive Stars in the Galaxy: Runaway Stars and Implications for Star Formation and Cluster Formation

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In recent years it has become apparent that many of the most massive (and therefore short-lived) stars in our Galaxy are to be found well away from known high mass star formation centers. There are two main possibilities for how this has become possible; massive stars can be born in relative isolation, or there are a number of fast-moving runaway massive stars that were ejected from stellar clusters. In this presentation we concentrate on the Wolf-Rayet star WR18 and its associated nebula NGC3199 a putative bow-shock formed ahead of WR18, which appears to be a classic case for a massive star ejected from a young stellar cluster. We expand this in presenting a study of all Wolf-Rayet stars for which there are GAIA proper motions in the first data release. The study indicates little evidence for high proper motions and that these stars have likely not moved far from their birthplace. The implications for star and cluster formation are reviewed.

Searching for Wide-Orbit, Planetary-Mass Companions through PSF-Fitting of Spitzer/IRAC Archival Data

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The last decade has seen the discovery of a growing population of planetary-mass companions (< 20 M_Jup; hereafter PMCs) to young stars which are often still in the star-forming regions where they formed. These objects have been found at wide separations (> 100 AU) from their host stars, challenging existing models of both star and planet formation. Do these systems represent the low-mass end of the stellar binary model? Are they an extremely high-mass scenario of current planet formation theories? Determining the answers to these questions will come once a statistically robust sample of directly imaged planets are observed and characterized.

The Spitzer mission obtained a wealth of deep and wide imaging of nearby molecular clouds and cores, including complete Spitzer/IRAC maps of very major star-forming region within 300 pc. This extensive data set of nearby star-forming regions and associations has great potential to be mined for wide companions to stars. Spitzer/IRAC is able to resolve PMC systems with projected separations of 1-10 arcseconds and is sensitive enough to detect the photospheres of proto-brown dwarfs and protoplanets (M_lim = 1 M_Jup at 1 Myr and 2 M_Jup at 5 Myr, according to the DUSTY models of Chabrier et al. 2000). Spitzer/IRAC limits are even deeper for hosts of circumplanetary disks, which add substantial infrared excesses.

In this talk, I will discuss current developments of an automated pipeline to find wide-orbit PMCs of stars via point spread function (PSF) subtraction in Spitzer/IRAC images. A Markov Chain Monte Carlo (MCMC) algorithm is the backbone of this PSF subtraction routine that efficiently creates and subtracts χ^2-minimizing instrumental PSFs, simultaneously measuring astrometry and infrared photometry of these systems across the four IRAC channels (3.6 μm, 4.5 μm, 5.8 μm, and 8 μm). I will present a re-analysis of archival Spitzer/IRAC images of 11 young, low mass (0.044-0.88 M_Sun; K3.5-M7.5) stars in 3 nearby star-forming regions (Chameleon, Taurus, and Upper Scorpius; ~150 pc) known to host faint companions over a range of projected separations (1.7-7.3 arcseconds). Finally, I will discuss the prospect for an automated companion search of all known young stars with existing Spitzer/IRAC data and describe potential avenues for follow-up observations of candidate binary and PMC systems.

Herschel PACS Observations of 4-10 Myr old Classical T Tauri Stars in Orion OB1

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We present new Herschel PACS observations of 8 Classical T Tauri Stars in the ~7-10 Myr old OB1a and the ~4-5 Myr old OB1b Orion sub-asscociations. Detailed modeling of the broad-band spectral energy distributions, particularly the strong silicate emission at 10 microns, shows that these objects are (pre)transitional disks with some amount of small optically thin dust inside their cavities raging form ~4 AU to ~90 AU in size. We obtained Spitzer IRS spectra for two objects in the sample: CVSO-107 and CVSO-109. The IRS spectrum of CVSO-107 indicates the presence of crystalline material inside its gap while the silicate feature of CVSO-109 is characterized by a pristine profile produced by amorphous silicates; the mechanisms creating the optically thin dust seem to depend on disk local conditions. Using millimeter photometry we estimated dust disk masses for CVSO-107 and CVSO-109 of less than 10 earth masses which indicates that giant planet formation should be over in these disks. The presence and maintenance of optically thick material in the inner regions of these mature pre-transitional disks points to low-mass planet formation.

Spectroscopic Survey of 400 1000 au Companions to Orion Young Stellar Objects

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We present results from a spectroscopic survey of 59 binary young stellar objects (YSOs) with separations between 100 and 1000 au using IRTF/SpeX and HST/WFC3. These YSOs, including both protostars and more evolved stars with discs, were identified in an HST NICMOS and WFC3 1.6 micron survey of 326 YSOs in the Orion molecular clouds (Kounkel et al. 2016). The aim of this investigation is to determine the spectral types and extinctions of the primaries and companions using near-infrared spectroscopy and to place them on an HR diagram. Of particular interest is the mass distributions of the primary and companions: whether they are similar - which could imply the binaries form from the fragmentation of the natal core, or whether the companions have much lower masses - suggesting that they form by the fragmentation of the discs surrounding the primaries with possible ejection onto wider orbits. Using low-resolution spectra, we simultaneously find the spectral type, extinction and disc-excess of each component member. Distinguishing between those objects which show photospheric features, namely deep water absorption, from the featureless, protostellar spectra (typical of the faint, HST observed systems), we present the distribution of spectral types and HR diagram for a sample of sources observed with either SpeX on the IRTF or with G141/WFC3 grism on HST having separations of 400 – 1000 au and explore what this distribution may say about the mass-ratio distribution of these systems.

ALMA and HST imaging of Orion Protostars

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Spatially resolving the structure and kinematics of protostellar envelopes is an essential steps toward understanding the physical processes that establish the masses of stars and shape the properties of proto-planetary disks. We report HST. 1.6 micron image (80 au resolution) of 283 protostars and ALMA C18O 13CO and 12CO (2-1) images (600 au resolution) of four edge-on protostars identified in the HST data. Imaging with HST shows outflow cavities carved in the envelopes. Using evolutionary indicators determined with the 1.6 to 870 micron SEDs from HOPS (the Herschel Orion Protostar Survey), we find no systematic growth in outflow cavities as protostars evolve. We also find protostars that have accreted most of their mass, have low density envelopes, and yet have narrow outflow cavities. We conclude that envelope clearing by the growth of outflow cavities is not the primary process for halting mass infall. We also examine the ALMA data of four edge-on protostars selected from the HST data. We detect the acceleration of the material by the central protostars. The data are not consistent with axisymmetric, rotating collapse models. In the two best studied examples (see figure), we find that the envelope structure is asymmetric, that the infall is also asymmetric, and that there is no coherent rotation of the envelope.

ALMA detections of asymmetric dust and growing grains in the disc of HD100546

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The disc around intermediate mass star HD100546 is one that has fascinated researchers of protoplanetary discs. Classified as a transitional disc and frequently showing evidence of active planet formation it is often referred to as an 'excellent laboratory for planet formation'.
Using new ALMA observations we have been able to characterise the distribution of gas and dust in the disc using 1.3mm continuum and emission from CO isotopologues, including the first detection, and subsequently the first resolved images, of C18O in the disc.

Combining these data with archival ALMA observations, we detect an azimuthal asymmetry in the outer dust disc. Asymmetries at large separations such as this are unusual (peaking at ~100au), furthermore the observed flux suggests that up to 1/4 of the total dust mass is distributed asymmetrically. Through calculating a radially-dependent spectral index we also find evidence that the dust grains in the disc have grown beyond mm sizes, and these large grains can be detected for the majority of the extent of disc. 'Weighing' the gas and dust emission provides disc masses and a provides a low gas to dust ratio in comparison to the canonically assumed ISM value of 100:1, in line with recent results from star forming regions. Together these results of growing grains, perturbed dust distributions and low gas mass confirm to us that HD100546 is caught right in the midst of its 'transitional' stage.

The imprint of X-ray photoevaporation of planet-forming discs on the orbital distribution of giant planets

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Recent exoplanet surveys have highlighted the existence of an impressive diversity of planetary systems, raising the question of how systems similar to our own can form and develop. The key to explaining the diversity of planetary systems is in the understanding of the statistical trends that are emerging from the recent wealth of exoplanet data. Understanding what controls the architecture of new-born systems is crucial to assess their habitability. Especially the location of giant planets can play a major role for the emergence of life, as they can shield habitable planets from severe impacts by asteroids or comets. They also play a central role in the delivery of volatiles to terrestrial planets. One of the well-known trends is the non-uniform distribution of the semi-major axes of gas giants. Giant planets are found to preferentially clump up at orbital radii of ~1-2 au and finding what determines this peak is of strong interest. It has recently been suggested that this distribution may be established during the time of planetary migration in the protoplanetary disc, being halted by X-ray driven photoevaporation (Ercolano & Rosotti, 2015). We have searched for signatures of this process by correlating the X-ray luminosity of host stars with the semi-major axis distribution of their giant planets. Our statistical analysis of the observational data confirms a prominent feature that is also predicted by theoretical simulations, further strengthening the conclusion that X-ray photoevaporation may not only be driving disc-dispersal, but also shaping the architecture of planetary systems.

Dense gas kinematics and a narrow filament in the Orion A OMC1 region using NH3

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We present combined observations of the NH3 (J, K) = (1, 1) and (2, 2) inversion transitions towards OMC1 in Orion A obtained by the Karl G. Jansky Very Large Array (VLA) and the 100 m Robert C. Byrd Green Bank Telescope (GBT). With an angular resolution of 6□□ (0.01 pc), these observations reveal in unprecedented detail the complex filamentary structure extending north of the active Orion BN/KL region in a field covering 6□ L 7□. We find a 0.02 pc wide filament within OMC1 with an aspect ratio of ~17 that has been missed in previous studies. Its orientation is directly compared to the relative orientation of the magnetic field vectors from the James Clerk Maxwell Telescope (JCMT) BISTRO survey in Orion A. We find a small deviation of 8□□ 15□ between the mean orientation of the filament and the magnetic field, suggesting that they are aligned almost parallel to one another. The filament s column density is estimated to be 23 orders of magnitude larger than the filaments studied with Herschel and is possibly self-gravitating given the low values of turbulence found. We further produce maps of the gas kinematics by forward modelling the hyperfine structure of the NH3 (J, K) = (1, 1) and (2, 2) lines. The resulting distribution of velocity dispersions peaks at 0.5 km/s, close to the subsonic regime of the gas. This value is about 0.2 km/s smaller than previously measured in single-dish observations of the same region, suggesting that higher angular and spectral resolution will identify even lower velocity dispersions that might reach subsonic turbulence in dense gas filaments.

Preliminary Results from a Young Exoplanet RV Survey

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Observing and characterizing newly-formed planets around young stars is important for developing planet formation and evolution theory. However, given challenges in detecting young planetary systems, current models are primarily based on systems that are billions of years old. It is therefore unclear which exoplanetary properties are indicators of formation conditions, or of later evolution. We are conducting an infrared radial velocity (RV) survey to detect and confirm young exoplanets around T Tauri stars using the Immersion Grating Infrared Spectrograph (IGRINS) on the 4.3-m Lowell Observatory Discovery Channel Telescope (DCT). IGRINS simultaneously observes H- and K-bands at a resolution of ~45,000. The IGRINS + DCT system can achieve a RV precision of ~40 m/s, is sensitive to giant planets within ~3 AU of a host star, and is relatively immune to RV variability triggered by starspots on active young stars. Our sample consists of ~140 T Tauri stars of age ~1-5 Myr in the relatively nearby Taurus star forming region. We aim to 1) detect and confirm young exoplanets; 2) compare hot Jupiter occurrence rates for pre-main sequence stars to those of main sequence stars; 3) investigate interactions between a circumstellar disk and planets; 4) extend these results to planet formation theory. We report early results on our search for RV variability of T Tauri stars, indicative of the presence of hot Jupiters with the IGRINS + DCT system, with a focus on follow-up of young planet candidate host stars.

Migration of seven low-mass planets around dwarf star TRAPPIST-1: early dynamical evolution in their protoplanetary gaseous disc

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We study the orbital evolution of seven low-mass planets embedded in a gaseous protoplanetary disc around the dwarf star like TRAPPIST-1, by carry out 3D hydrodynamical simulations with the FARGO3D code. The initial conditions in our simulations for the masses of the central star and the seven planets, as well as the semimajor axis of the planets were taken from Gillon et al. We believe that the resonant behavior that currently shows the planetary system TRAPPIST-1 is a consequence of a quasi-stationary migration. The planet disc interaction is more complex due to nearness between seven planets and the inward migration is not possible. We found that the seven planets are in compact configuration they hold in Mean Motion Resonance (MMR), another case the planetary system is unstable.

Disk Sizes and Grain Growth across the Brown Dwarf Boundary from the Taurus Boundary of Stellar/Substellar (TBOSS) Survey

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With a combination of submm/mm observations from ALMA, CSO, and PdBI, we are investigating the properties of disks around low mass stars and brown dwarfs in the Taurus star-forming region. Disk sizes and spectral slopes are important properties to assess the formation scenarios for brown dwarfs and the viability of planet formation in the disks. The ALMA maps have a beam size of approximately 0.3arcseconds and a number of the sources are spatially resolved in the continuum and CO(3-2) line measurements. For most of the resolved systems, the gas disks are more extended than the dust disks, similar to previous results from observations of more massive stars. From the multi-wavelength data, we are measuring the spectral slope of the emission to search for the signature of initial grain growth that is encoded in the slope of the spectral energy distribution in order to test the hypothesis of enhanced radial drift in disks around substellar objects. Theoretical studies have suggested that fast radial drift could prevent the growth of dust particles up to large bodies in brown dwarf disks, and our program is designed to obtain a set of measurements for objects across the stellar/substellar transition.

Orbital motion of the long period exoplanet GSC 6214-210b

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Directly imaged planet surveys have discovered a class of 5-20 Mjup substellar companions at separations >100 AU from their hosts stars. These wide planetary mass companions (PMCs) present a challenge to our understanding of how a planetary system forms around a star. Most are too far from their star, and too massive, to be accounted for by current planet formation models, but less massive than typical stellar binary companions. PMCs might form in situ, but could also form at small radii and be scattered out to their current orbit through dynamical interactions. Scattering would leave its mark in the orbit that the PMC is on today. Constraining the orbital parameters allowed by current orbital velocities for this population group can provide insight into their formation pathways. We present the relative astrometry for the wide PMC GSC 6214-210b obtained using the NIRC2 Adaptive Optics camera at Keck telescope in Hawaii spanning several observation epochs. Our measurements achieved astrometric uncertainties near the NIRC2 systematic limit (~1-2 mas), allowing measurement of the tangential orbital velocity with robust uncertainty determination. We also present constraints on orbital parameters determined through our modified implementation of the Orbits for the Impatient rejection sampling algorithm (Blunt et.al. , 2010.). We then discuss the implications of these parameters for the likelihood of a previous scattering interaction with another companion.

Pebble accretion in laminar and turbulent discs

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Planets are born in protoplanetary discs growing from very small particles to full-grown planets. The growth process has to cover many orders of magnitude in mass and has to finish within the lifetime of the disc which lasts only a few million years.
In the past years, it has been recognized that the growth process can be sped-up by accreting a large number of solid pebble-sized objects that are still present in the protoplanetary disc. It is still an open question how efficient this process works in realistic turbulent discs.
Here, we investigate the accretion of pebbles in turbulent discs that are driven by the purely hydrodynamical vertical shear instability (VSI). For this purpose, we perform global three-dimensional simulations of locally isothermal, VSI turbulent discs with embedded protoplanetary cores from 5 to 100 Earth masses. In addition, we follow the evolution of a swarm of embedded pebbles of different size under the action of drag forces between gas and particles in this turbulent flow. Simultaneously, we perform a set of comparison simulations for laminar viscous discs where the particles experience stochastic kicks. For both cases, we measure the accretion rate onto the cores as a function of core mass and Stokes number of the particles.
Overall the dynamic is very similar for particles in the VSI turbulent disc and the laminar case with stochastic kicks. For well-coupled particles with St = 1, which have a size of about one meter at this location, we find an accretion efficiency (rate of particles drifting inward over particle accretion rate) of about 5-10%. For smaller and larger particles this efficiency is higher. However, the fast inward drift for St=1 particles makes them the most attractive for rapid growth, leading to mass doubling times of about 6,500 yrs for our low mass planets. For masses between 10 and 30 Earth masses, the core reaches the pebble isolation mass and the particles are trapped at the pressure maximum just outside of the planet, shutting off further particle accretion.

Astrophysics of Young Visual Binaries

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Stellar and circumstellar properties of young binaries reveal unique insight into star and disk formation and evolution. Multiple systems provide an approach to control for some factors which influence star formation because systems with separations of a few to a few hundred astronomical units share a common composition and environment. We are completing analysis of about 100 Taurus and Ophiuchus pre-main sequence visual binaries and triples. This poster will highlight recent, exciting results. All reduced spectra and preliminary analysis will be publicly available to the community at
http://jumar.lowell.edu/BinaryStars/.
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Eccentricity evolution during planet-disc interaction

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During the process of planet formation, the planet-discs interactions might excite (or damp) the orbital eccentricity of the planet. In this poster, we present two long (t ~ 3x10^5 orbits) numerical simulations: (a) one (with a relatively light disc, M_d/M_p=0.2) where the eccentricity initially stalls before growing at later times and (b) one (with a more massive disc, M_d/M_p=0.65) with fast growth and a late decrease of the eccentricity. We recover the well-known result that a more massive disc promotes a faster initial growth of the planet eccentricity. However, at late times the planet eccentricity decreases in the massive disc case, but increases in the light disc case. Both simulations show periodic eccentricity oscillations superimposed on a growing/decreasing trend and a rapid transition between fast and slow pericentre precession. The peculiar and contrasting evolution of the eccentricity of both planet and disc in the two simulations can be understood by invoking a simple toy model where the disc is treated as a second point-like gravitating body, subject to secular planet-planet interaction and eccentricity pumping/damping provided by the disc. We show how the counterintuitive result that the more massive simulation produces a lower planet eccentricity at late times can be understood in terms of the different ratios of the disc-to-planet angular momentum in the two simulations. In our interpretation, at late times the planet eccentricity can increase more in low-mass discs rather than in high-mass discs, contrary to previous claims in the literature.

Kinematics of Gravitational Unstable Disk, L1448N

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ALMA dust continuum observations of the nearby ($\sim$230~pc) triple protostar system L1448 IRS3B have resolved spiral structure originating from an inner ($\sim$60~AU) binary with a third protostellar companion embedded ($\sim$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 of the disk formed the multiple system.

The spiral structure does not shed light unto the disk kinematics, however, molecular emission can; C^{17}O (J=3-2) traces the rotation of the disk very well at both high and low velocities due to the low optical depth of the isotopologue through the cloud. Simple analysis shows the disk is consistent with Keplerian rotation about a central mass of 0.9$\pm$0.1~M$_{\odot}$ and a disk mass of 0.025 M$_{\odot}$.

We model the observed C^{17}O channel maps using a Markov-Chain Monte-Carlo (MCMC) method and Bayesian statistics in tandem with a radiative transfer code to better constrain and examine the disk kinematics. Bayesian methods provide a rigorous statistical way to determine the most probabilistic generated model from the resulting MCMC fit. We further discuss the implications of our results on the formation of multiple systems in L1448 IRS3B and in other systems.

Survey of high resolution mid-infrared water emission from protoplanetary disks

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I will present results from the largest survey to date of spectrally resolved mid-infrared water emission from protoplanetary disks, with data from the Michelle and TEXES spectrographs on Gemini North. Water emission is commonly detected from classical T Tauri stars --- 6 out of 8 within our sample. On the other hand, water emission is not detected in the transitional disks SR 24 N and SR 24 S, in spite of SR 24 S having pre-transitional disk properties like DoAr 44, which does show water emission (Salyk et al. 2015). With R=100,000, the TEXES spectra represent the highest spectral resolution observations of water vapor possible at this time, and allow for analysis of emission line shapes. The emission lines are either single or double-peaked. Single peaked emission lines are difficult to produce with a standard disk model, and suggest that water participates in the disk winds believed to explain single-peaked CO emission lines (Bast et al. 2011; Pontoppidan et al. 2011). Double peaked emission lines can be used to determine the radius at which the line emission luminosity drops off. For HL Tau, the measured dropoff radius is consistent with the measured 13 AU dark ring seen with ALMA (ALMA partnership et al. 2015). We also find variable emission line strengths from the disk around RW Aur, which is consistent with the tidal arm blocking scenario suggested by (Rodriguez et al. 2013).

Prevalent Organic Molecules towards Prestellar Cores in the Taurus Star Forming Region

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The detection of complex organic molecules (COMs) toward dense, starless (prestellar) cores has sparked interest in the fields of astrochemistry and astrobiology, yet the reason for COM formation remains a mystery. Since a prestellar core is the primitive phase of core evolution, it can best constrain the initial chemical conditions of star and planet formation. It was initially believed that COMs form in ices within the outer layers of cores, which are then irradiated by UV radiation from the surrounding interstellar radiation field, and are subsequently photo-desorbed into the gas phase. However, prestellar cores themselves are cold (~10K) and lack strong radiation fields, therefore a different process must be occurring. Reactive chemical desorption is the leading idea, which suggests that precursor molecules to COMs form on icy surfaces of interstellar grains which then get ejected into the gas by the heat from chemical reactions and subsequently form the COMs by fast gas phase reactions. Studies to date have all pointed to only a few well-known dense starless cores. We ve conducted the first ever large-scale, systematic survey of the complete starless/prestellar core population (31 sources) in the central Taurus molecular cloud, looking for emission from COMs. All of our cores span a range of dynamical and chemical stages, thus we ve quantified how prevalent COMs are toward prestellar cores and how quickly they form. Surprisingly, we have detected methanol (CH3OH) in all 31 cores as well as acetaldehyde (CH3CHO) in a large subset, suggesting organic molecules are much more prevalent that previously expected.

Post outburst look at the chemical tracers and the protoplanetary disk around HOPS 383

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HOPS 383, a Class 0 embedded protostar in Orion, is the youngest known outbursting Young Stellar Object (YSO). Understanding the cause and effects of the outburst in HOPS 383 can give essential insight into the process of episodic accretion during the early stages of star formation. We observe the chemical tracers surrounding HOPS 383 using the Submillimeter Array (SMA) at 0.85 mm, 1.1 mm, and 1.3 mm. Our observations show peaked HCO+ and H13CO+ and reduced N2H+ at the protostar position. N2H+ is double-peaked and surrounds the protostar. These results are in good agreement with chemical models of outbursting YSOs where the evaporating CO increases HCO+ and decreases N2H+. In addition, results from the Atacama Large Millimeter/submillimeter Array (ALMA) and the Very Large Array (VLA) show continuum emission with a well resolved-disk. The disk is powering a well-collimated 12CO outflow, evident both in the SMA and the ALMA data, suggesting that HOPS 383 is quite young. We also model the disk using Markov-Chain Monte-Carlo (MCMC) including 3D radiative transfer code to analyze various disk parameters such as the mass of the disk. More sensitive and higher resolution data with molecular lines are needed to clarify the cause of the outburst and the stability of the protostellar disk.

Constraints on Embedded Disk Masses and Structure as Seen by CARMA and ALMA

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Class I protostars are thought to represent an early stage in the lifetime of protoplanetary disks, when they are still embedded in their natal envelope. As such, they provide an opportunity to measure the initial masses of protoplanetary disks, before significant dust processing and planetesimal formation has hidden mass in larger bodies. We have conducted a large survey of Class I protostars, initially with CARMA but now continuing with ALMA, to study the structure of their disks and measure their masses. We fit radiative transfer models to our sample and find that Class I have similar structure to Class II disks. However, our measurements show that Class I disks are, on average, more massive than the older Class II disks. The discrepancy between the Class I disk mass distribution and the Minimum Mass Solar Nebula and giant planet occurrence rates is not as severe as it is for Class II disks. As such, Class I disks may be a good representation of the initial masses of protoplanetary disks. However, we will also present results which suggest that planet formation may already be underway in Class I disks.

JSmallwood_DiskAlignment_1

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With three-dimensional hydrodynamical simulations we show that the evolution of initially misaligned circumbinary disks around eccentric binaries is significantly different to around circular binaries. Depending upon the initial disk inclination and the binary eccentricity, the disk aligns either with the binary angular momentum vector or the binary eccentricity vector. In both cases we find large oscillations of the inclination of the disk during the alignment process. This evolution has important implications for planet formation around eccentric binary star systems.

Studying Hierarchical Structure Through Time in Star Formation Simulations

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Understanding star formation has become ever more critical in the recent era of exoplanet science. However, there is still ambiguity in the time evolution of the properties of star forming cores and how that may relate to properties such as multiplicity. We have developed an algorithm to link hierarchical structures in hydrodynamic simulation of star forming regions in time. With this information, we can study the temporal evolution of individual core properties. We investigate conditions that lead to the formation of sink particles and identify properties that correlate with the formation of bound multiple systems of sink particles. This work will help us create a detailed understanding of star formation and will allow us to create a coherent picture of core evolution from beginning to end.

The Disk Settling Instability: fast clumping of small grains in protoplanetary disks

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We identify and characterize the disk settling instability, a variant of the streaming instability (Youdin & Goodman 2005) that can occur in protoplanetary disks when grains settle vertically into the midplane region. The growth rate of the settling instability is independent of grain size and comparable to the disk orbital frequency for realistic parameters, suggesting that the instability is relevant for even the smallest grains. In addition, its characteristic wavelengths are larger than those of the streaming instability, potentially allowing the instability to concentrate large masses of solids. These properties suggest that in the process of settling, small grains could band into rings (then filaments or clumps) with significantly higher than background metallicity. This could have a variety of important consequences for the early stages of planetesimal formation, for instance, by enhancing coagulation rates of small grains and/or creating high-metallicity regions in the midplane that act to seed the standard streaming instability.

HST Imaging of Edge-on Circumstellar Disks in Nearby Star-Forming Regions

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We discuss multicolor HST optical imaging results for fifteen edge-on circumstellar disks uncovered in our surveys of YSOs in the Perseus, Auriga, Taurus, Chamaeleon, Lupus, and Ophiuchus molecular clouds. The target selection was based on the shapes of their spectral energy distributions as seen by the Spitzer Space Telescope in data from the c2d, Taurus, and Gould s Belt Legacy Science Programs. Outstanding individual objects (a large, symmetric disk; a flat disk around a weak-line T Tauri star; a distorted disk in a close binary system; and a disk with an apparent companion at its outer edge) have been followed up with millimeter interferometry and AO imaging. We show that the frequency of YSOs with SEDs consistent with edge-on disks is well below the fraction predicted from model disks observed from random inclinations. Possible reasons for this discrepancy will be discussed.

Thermal-Infrared Observations of Planets and Protoplanets with ALES

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I am commissioning and upgrading ALES, the world's only thermal-infrared integral field spectrograph, and performing a survey of directly imaged exoplanets with the instrument. Thermal-Infrared constraints are essential for building an accurate understanding of gas-giant exoplanet atmospheres because they help to break degeneracies between effective temperature, cloudiness, and non-equilibrium chemistry that exist with near-infrared constraints alone. Improved measurement of atmospheric composition will help disentangle gas-giant formation mechanisms. ALES upgrades will improve performance at high-spatial resolution and include two prongs: 1) modifying the existing optics to facilitate interferometric observing with LBTI to take advantage of the 23 m inter-aperture baseline and resolve the giant-planet forming regions in disks about stars in the Taurus/Auriga, and 2) co-aligning ALES optics with an extant vector vortex coronagraph, which will result in the deepest L' contrast curves ever obtained.

Examining Veiling and Accretion around the Young Binary Stars S Corona Australis and VV Corona Australis

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In order to understand the likelihood of planet formation in various types of binary and higher-order multiple systems, we must consider young binary star systems that are the future sites of planet formation i.e., they have accreting circumstellar or circumbinary disks, and are still surrounded by envelopes of natal material. Envelopes accrete onto disks and disks in turn accrete onto the central stars, triggering elevated continuum emission, line emission, outflows, and stellar winds. By understanding the complex star-disk interactions at the earliest observable stages of stellar evolution, we may begin to draw a more complete picture of the processes that eventually cause many systems to form planets. We have used high-resolution near-infrared spectroscopy from the NIRSPEC instrument on the Keck telescope, taken over several epochs spanning five years, to examine two young binary T Tauri star systems, S Corona Australis and VV Corona Australis, in the southern star-forming region Corona Australis. Both of the stars in these intermediate-separation (170 and 250 AU, respectively) systems have circumstellar disks and are heavily obscured at most wavelengths. They are also similar spectral types (approximately K7-M1) and thus similar stellar masses, allowing robust comparison of the two systems. Using a combination of new and archival data we have determined the spectral types of all stars in these two systems, examined the variable NIR veiling, and have characterized the accretion onto S CrA.

Mean Motion Resonance Overlap in Migrating Circumbinary Systems

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We constrain the migrational history of circumbinary planets due to instabilities from overlapping mean motion resonances. Many of the discovered transiting circumbinary planets are located near the most interior stable orbits, suggested the planets have migrated to their current location. Disk driven planet migration in multi-planet systems is likely to trap planets in mean motion resonances. We show how planet-planet mean motion resonances can overlap with mean motion resonances with the binary, leading to instabilities. This allows us to analytically explore the migration rates, maximum eccentricity growth of circumbinary planets. We are also able to constrain the masses of additional undetected planets if the planets migrated while in resonance.

Inside-Out Planet Formation of the Super-Earths

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I present a short overview of the Inside-Out Planet Formation (IOPF) model (Chatterjee & Tan 2014, ApJ, 780, 53) for sequential in situ formation of the Kepler-discovered super-Earth population of close-in multi-planet systems at the pressure trap associated with a retreating dead zone inner boundary. I then discuss latest work exploring theoretical aspects of the model, including calculations of the structure of the inner disk, simulations of the gap opening process leading to pebble isolation and capture of H/He atmospheres. I end with a summary of observational tests of this planet formation model.

ATMOSPHERIC VARIABILITY INDUCED BY RADIATIVE CLOUD FEEDBACK IN BROWN DWARFS AND DIRECTLY IMAGED GIANT PLANETS

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Observational evidence has suggested that there is active meteorology in the atmospheres of brown dwarfs. In particular, a number of surveys of brown dwarfs have shown that near-IR brightness variability is common for L and T dwarfs. Similar near-IR variability has also been found for directly imaged extrasolar giant planets (EGPs), which can be viewed as low-gravity versions of brown dwarfs. A number of possibilities have been proposed as the driving sources for the variability in brown dwarf atmospheres, and yet they need further detailed demonstration. Clouds are believed to play an important role in shaping the thermal structure, spectral properties and perhaps dynamics of these atmospheres, and we expect the same for inducing short-term atmospheric variability. In this work we propose a robust mechanism for the variability in which condensational cloud cycles controlled by particle gravitational settling and convective mixing interact with thermal radiation via cloud opacity loading. This mechanism naturally drive oscillations in both temperature and cloud structure. We demonstrate the variability using a simple and self-consistent one-dimensional model. We show that the detailed evolution of variability is sensitive to the assumed cloud microphysics, but the existence of variability is robust for a wide range of model assumptions. Our proposed mechanism has important implications for the observed flux variability, especially brown dwarfs that evolve in a short timescale and with complex vertical structure. It is also a promising mechanism for cloud breaking, which has been proposed to explain the L/T transition of brown dwarfs.

Modeling Protoplanetary Disks in Galactic-Metallicity Environments

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Topic: Modeling Protoplanetary Disks

Modeling Protoplanetary Disks in Galactic-Metallicity Environments
We have obtained UV-mm spectral energy distributions of a small sample of candidate Herbig Ae/Be stars in the Small Magellanic Cloud (SMC). In an effort to determine how the structure of protoplanetary disks is different in the low-metallicity environment of the SMC, relative to the Milky Way, we are learning to use the RADMC-3D radiative transfer code. As a first step to insure that we understand the details of the modeling process, we have used the software to reproduce existing models of two Herbig Ae/Be disks that are well studied in the Milky Way: HD34282 and HD100453. We have successfully reproduced these models allowing us to infer the structure of the disks and make models that fit their observed spectral energy distributions. We have therefore begun to use the same techniques to model the SMC sample, which is the subject of another poster at this conference (see Holman et al.).

The gas and dust disk around the CQ Tau protostar

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The combination of high resolution and sensitivity offered by the Atacama Large Millimeter Array (ALMA) is transforming our understanding of protoplanetary disks, as their bulk gas and dust distributions can be studied independently. I will present resolved ALMA observations of the continuum (lambda=1.3 mm) and CO isotopologues (12CO, 13CO, C18O, J=2-1) line emission from the disk around the nearby (d = 160 pc), intermediate mass (M=1.5Msun) pre-main-sequence star, CQ Tau. Our focus is on finding the best representative model for the high-angular resolution observations of the protoplanetary disk around CQ Tau. The data show a clear inner cavity in the continuum emission and in the rarer CO isotopologue (C18O) line emission. For the data analysis we employ the physical-chemical code DALI, which self-consistently calculate the disk chemical structure, together with the disk gas and dust thermal structure. The aim is to characterize the dust and gas radial distributions. In particular, it is interesting to constrain the depth and extent of the inner cavity in both components, as this provides information on the possible planet clearing the inner disk. We find clear evidence of an inner cavity in the disk dust distribution with an outer radius of 28 AU. The dust depletion factor inside the cavity is of 1E-2. The gas distribution presents a smaller cavity, with outer radius between 15 AU and 25 AU, and a depletion factor between 1E-1 and 1E-3. We combine this study with hydrodynamical simulation in order to probe if the gas and dust distribution that we see can be compatible with the presence of a planet. Those simulations gave us also constraints on the mass and distance of the possible companion.

Unveiling the physical conditions of the youngest disks: a warm disk in L1527

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Disks around young stars are the birthplace of planets. The first steps of planet formation, that is, grain growth and maybe even the formation of larger bodies, already occur when the disk is still deeply embedded in its natal envelope (Class 0/I sources). Thus, these young disks, rather than the more evolved protoplanetary disks (Class II), likely provide the initial conditions for planet formation. However, the physical and chemical structure of embedded disks is poorly characterized. We have therefore analyzed archival ALMA observations of 13CO, C18O and N2D+ toward the edge-on disk of L1527 to constrain the disk temperature (van 94t Hoff et al., submitted). Based on these results we conclude that this Class 0/I disk is likely warm enough (T s 20 K) to prevent CO freeze-out. These results are in contrast with observations of Class II disks that show large cold (T r 20 K) gas reservoirs in the outer disk, but they are in agreement with model predictions for Class 0/I disks.

The temperature structure is one of the critical unknowns for young embedded disks, since this directly influences the volatile composition of the planet-forming material. Depending on the temperature, CO is either present in the gas phase (T s 20 K) or frozen out onto dust grains (T r 20 K). Since CO is a dominant carrier of carbon, desorption of CO will relatively deplete the ice of carbon, lowering the C/O elemental ratio. The C/O ratio in planetesimals thus strongly depends on whether the temperature is low enough for CO to freeze out. N2H+ observations toward several evolved protoplanetary disks have shown that the outer disk midplane becomes too cold for CO to stay in the gas phase. The N2H+ ion traces CO freeze-out because its main destructor is gas-phase CO (e.g., van 94t Hoff et al. 2017).

The disk around L1527 is particularly interesting for studies of the temperature structure; its almost edge-on configuration allows seeing the midplane directly, instead of through the disk s surface layers. The spatial extent of the 13CO and C18O J = 2-1 emission indicates that CO is present in the midplane throughout the disk and in the inner envelope. This is corroborated by the non-detection of the deuterated form of N2H+, N2D+. The optically thick CO isotopologues trace the kinetic temperature of the gas and have brightness temperatures s 25 K along the midplane. Although determining the exact radius at which the optically thick emission originates is not trivial, emission at the largest velocity offsets is expected to originate only in the disk. A power law radial temperature profile constructed using the brightness temperature at these velocities suggest that the temperature is higher than 20 K throughout a large fraction of the disk and possibly the entire disk. Moreover, radiative transfer modeling shows that a model without CO freeze-out in the disk matches the C18O observations better than a model with CO frozen out at radii larger than 70 AU (disk radii of 74 and 125 AU have been reported by Aso et al. 2017 and Tobin et al. 2013, resp.). In addition, no evidence of a significantly low CO gas-phase abundance is found.

Altogether, these results indicate that the embedded disk in L1527 is warm enough to prevent CO freeze-out, suggesting that young disks can be warmer than their more evolved counterparts as predicted by physical models.

V1094 Sco: a rare giant multi-ringed disk around a T Tauri star

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A wide variety of structures has been detected in protoplanetary disks, but their origin and frequency are still unclear. We characterize the structure of an extended, multi-ringed disk discovered serendipitously in the ALMA Lupus disk survey, and put it in the context of the Lupus disk population. ALMA observations in Band 6 and Band 7 at 0.3 resolution toward the K6 star V1094 Sco in Lupus III are presented, and its disk structure is analyzed. The spectral index α_{mm} is determined in the inner 150 AU of the disk. The ALMA continuum data show a very extended disk with two gap/ring pairs. The gaps are located at 100 AU and 170 AU, the bright rings at 130 AU and 220 AU. Continuum emission is detected out to a 300 AU distance, similar to IM Lup but a factor of 5 larger than typically found for Lupus disks at this sensitivity and resolution. The bright central region of the disk (within 35 AU) is possibly optically thick at 1 mm wavelengths, and has a brightness temperature of only 13 K. The spectral index increases between the inner disk and the first ring, at the location of the first gap. Due to the low temperature of the disk midplane, snow lines can be excluded as the drivers between the ring and gap formation in this disk. Disks the size of V1094 Sco are rare: only 2.1± 1.5% of disks in Lupus show continuum emission beyond 200 AU. We discuss possible connections between the large primordial disk population, transition disks, and exoplanets.

Can spirals and axisymmetric structures give us a proxy for the total disc mass? The particular case of HD135344B

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In the last years, the Atacama Large millimeter/submillimter Array (ALMA) and the Spectro-Polarimetric High-contrast Exoplanet Research (SPHERE) instrument at the VLT are giving us high resolution and high sensitivity observations of protoplanetary discs, showing peculiar substructures, such as spirals, gaps and horseshoes. Disc instabilities and planets have been proposed to be responsible of their formation, anyway, their origin is still very debated, in particular how their shape depends on the disc mass.
In this poster we will present results about the hydrodynamical modeling of the protoplanetary disc HD135344B (Garufi et al. 2013, van der Marel et al. 2016, Stolker et al. 2016, Maire et al. 2017), that shows a distinctive spiral structure in scattered light and an axisymmetric horseshoe in the dust continuum. By means of PHANTOM, a smoothed particle hydrodynamics (SPH) code, and of RADMC-3D, a MonteCarlo Radiative Transfer code, we performed dynamical and thermodynamical simulations of a protoplanetary disc with two embedded planets, varying the gaseous mass and the aspect ratio (H/R) of the disc. We found out that the spiral structure, observed in scattered light, is quite well reproduced by a massive planet in the outer region of the disc. However, it is still not completely clear if the horseshoes like structure could have been originated by the same outer planet.
Furthermore, I will present preliminary results in order to find out if it is possible to estimate the total disc mass in protoplanetary discs by the combined hydrodynamical modeling of planet-induced disc substructures observed in scattered light (micron-sized grains) and in the dust continuum (mm-sized grains). To pursue this aim, we are performing SPH simulations of a protoplanetary disc with two embedded planets, varying the gas mass component.

Probing dust and gas evolution in protoplanetary disks. The pivotal Chamaeleon II association.

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In the context of planetary formation, the formation and evolution of a disk around a young star are crucial steps. Several mechanisms drive the evolution and dispersal of disks and each of them will have an impact on the appearance of the protoplanetary disks, hence, on our capacity to extract direct observational constraints. Constraining disk evolutional lifetime is essential to understand mechanisms at play, in particular planet formation that has to happen before the disk has dissipated.

In this talk, I will present our results based on the study of a sample of 31 protoplanetary disks in the Chamaeleon II dark cloud, using ALMA Cycle 2 data (age of 4 ± 2 Myr). We characterize dust fluxes, sizes and masses, and compare them to the gas ones. Then, by comparing our results to those in other star forming regions, such as Lupus (< 1–3 Myr) or Upper Sco (< 11 Myr), we constrain the typical disk mass evolution timescales in different environments and find a typical value of ~1.5 Myr. From cumulative mass distributions for differently aged star forming regions, we find that disks in old regions seems to be lighter than disks located in younger regions. Considering gas evolution by comparing [OI] or CO isotopologues detections rates in several star forming regions, we found that old regions seems to have less gas than younger regions, in accordance to disks dissipation models. We also inferred that gas seems to dissipate faster than dust.

The Orbit of the Companion to HD 100453A: Binary Driven Spiral Arms in a Protoplanetary Disk

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We report new results from our study of the disk structure and evolution in the spiral protoplanetary disk hosting binary, HD 100453. This disk represents the only known grand-design (two-armed) spiral protoplanetary disk in which a low-mass companion has also been detected. We present the first constraints on the companion's orbit, utilizing data from VLT/NACO, VLT/SPHERE, and Magellan/MagAO. We also constrain the disk inclination from ALMA CO observations and gas kinematic modeling. We find that the companion's orbital semi-major axis (105 ± 15 au) is 3-4 times greater than the observed extent of the disk, and that the companion orbits in the same plane of the disk to within measurable limits (±10°) on a low eccentricity orbit (e<0.3), in accordance with a classical disk truncation scenario. We utilized these constraints on the system geometry in combined hydrodynamic and radiative transfer simulations, and find in all cases that the companion generates a prominent two-armed spiral pattern in the simulated disk imaging that is in qualitative agreement with the observed disk structure. This system represents a benchmark in understanding the formation of spiral arms in protoplanetary disks, and has implications for on-going planet searches in the other two similar disks that do not host binary companions, but nevertheless host similar spiral structures.

Low Radio Flux of Planet-mass Companions: Compact Circumplanetary Disks?

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Planet-mass companions discovered in high-contrast imaging surveys are ideal to search for the presence of circumplanetary disks because they are widely separated from their host stars. I will present our ALMA observations on planetary companions. We find that FW Tau C has a dynamical mass of 0.1 solar masses, so it is actually a low-mass star. We also suggest that disks around wide companions are probably very compact, so they are faint and optically thick in radio wavelengths. Mid-infrared observations with JWST may be able to constrain disk sizes.

Young Stars in the Tumultuous Gum Nebula

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We conduct a high-dispersion (R ~34,000) optical spectroscopic pilot study of young stars in the Gum Nebula, a complex, windy region uniquely home to cometary globules. We examine 10 young stars, of which CG 30 IRS4 is the first confirmed infrared source in a cometary globule with stellar photospheric features. PHa 41 is a young binary. All our targets are low-mass (spectral types M4.5 - K5) stars with broad Ha emission and significant spectral veiling, indicating accretion from a circumstellar disk. This, paired with strong Li absorption and high rotational velocities, suggests these stars are no more than 5 Myr old. Though spatially close (within 10 pc of each other assuming a distance of 400 pc), their radial velocity spread (~10 km/s) would be abnormally large for low-mass stars recently formed together. Our sample may comprise two separate populations; GAIA's imminent data release will constrain distances and kinematics. Our long-term goal is to use the properties of these young stars to more completely map young stellar populations in the center of the northern edge of the Gum Nebula, and to further understand star and potentially planet formation in blustery conditions.