Science Program Book

for

Fifth Spitzer Science Conference

New Light on Young Stars: Spitzer's View of Circumstellar Disks

October 26-30 2008

http://www.ipac.caltech.edu/spitzer08

Thanks to the guidance of the Science Origanizing Committee:

Deborah Padgett (chair)

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Sean Carey

Neal Evans

Lynne Hillenbrand

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Jonathan Tan

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Sunday, October 26, 2008

10:00 am	**Van leaves for Huntington Tour** (Hilton)
$\sim$ **4:00**	**Huntington Tour Returns**
4:00	**Registration Opens** (Foyer, Hilton)
4:00	**Posters go up** (California and International Ballrooms, Hilton)
5:00 - 7:00	**Poster Session and Registration** (California and International Ballrooms, Hilton)
5:00 - 7:00	**Opening Reception with Cash Bar** (California and International Ballrooms, Hilton)

Monday, October 27, 2008

Census of Young Disks in the Galaxy

7:30 am	**Coffee** (California Ballroom, Hilton)	
	Plenary session (International Ballroom, Hilton)	
8:15	*Deborah Padgett*	Welcome and Logistics
8:30	*Neal Evans*	Initial Conditions - Transition from Cores to Disks
9:20	*Jes Jørgensen*	Observations of the Earliest Stages of Protostellar Disks
9:40	*Dan Watson*	Rainfall from Protostellar Envelopes onto Protostellar Disks
10:00	Coffee and Poster Session (California Ballroom, Hilton)	
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11:20	*Thomas Robitaille*	Spitzer Observations of Young Stellar Objects Throughout the Milky Way
11:40	*Joseph Hora*	The Spitzer Legacy Survey of the Cygnus-X Region
12:00 pm	Lunch and Posters	
1:30	*Tom Megeath*	Disk Frequency and Distribution in OB Associations
2:20	*Jonathan Williams*	Disk Masses in the Orion Trapezium Cluster
2:40	*Scott Wolk*	Spitzer and X-ray Observations of Star Forming Regions
3:00	*Aleks Scholz*	Brown Dwarf Disks in the Spitzer Era
3:20	Coffee and Poster Session (California Ballroom, Hilton)	
4:00	*Lori Allen*	Disks in Nearby Low Mass Star-forming Regions
4:50	*Fernando Comerón*	What Spitzer Missed: New Members of Lupus 3 That Don't Advertise Their Youth
5:10	Poster Session with Hosted Bar (California Ballroom, Hilton)	

Tuesday, October 28, 2008

Characterization of Young Stellar Disks

8:00 am	**Coffee** (California Ballroom, Hilton)	
	Plenary session (International Ballroom, Hilton)	
8:30	*Nuria Calvet*	Issues in Protoplanetary Disk Modeling
9:20	*Shatanu Basu*	The Formation and Evolution of Protostellar Disks
9:40	*Neal Turner*	Understanding Spitzer Observations of Protostellar Disks Using 3-D MHD Calculations
10:00	Coffee and Poster Session (California Ballroom, Hilton	
10:30	*Bruno Merin*	The Observed Diversity of YSO Disk Properties
11:20	*Colette Salyk*	IRS Detections of Water Vapor in Protoplanetary Disks
11:40	*William Forrest*	High Temperature Silica in Protoplanetary Disks
12:00 pm	Lunch and Posters	
1:30	*Jeroen Bouwman*	Disk Composition from Spectra
2:20	*Johan Olofsson*	Coagulation and Crystallization of Silicates in Protoplanetary Disks: A c2d Spitzer/IRS Survey
2:40	*Klaus Pontoppidan*	Imaging of molecular gas in Protoplanetary Disks on 1 AU Scales Using Spectro-astrometry
3:00	Coffee and Poster Session (California Ballroom, Hilton	
3:40	*David Wilner*	Spatially Resolved YSO Disk Studies - Present and Future
4:30	*Andrea Isella*	CARMA Observations of Protoplanetary Disks: Initial Conditions and Evolution
4:50	*Sean Andrews*	Protoplanetary Disk Structure with the SMA
5:10	Poster Session with Hosted Bar (California Ballroom, Hilton	

Wednesday, October 29, 2008

Transition Disks and Disk Evolution

8:00 am	**Coffee** (California Ballroom, Hilton)	
	Plenary session (International Ballroom, Hilton)	
8:30	*Eugene Chiang*	From T Tauri Disks to Transitional Disks: Accretion and Planetesimal Formation
9:20	*Jesus Hernandez*	Disk Census in the Star-Forming Regions of the Orion OB Associations
9:40	*Adam Kraus*	The Role of Multiplicity in Protoplanetary Disk Evolution
10:00	Coffee and Poster Session (California Ballroom, Hilton)	
10:30	*Richard Alexander*	Gas Phase Processes in Disk Evolution
11:20	*Manuel Guedel*	Is Mid-Infrared [Ne II] Emission a Tracer for X-Ray Ionized and Heated Gas in Protoplanetary Disks?
11:40	*Sean Brittain*	The Observation of Warm Gas in Transitional Disks Around Herbig Ae/Be Stars
12:00 pm	Lunch and Posters	
1:30	*Joan Najita*	Gas in YSO and Transition Disks
2:20	*Elise Furlan*	Disk Evolution in Taurus, Ophiuchus, and Chamaeleon I
2:40	*James Muzerolle*	Spitzer Census of Transition Disks
3:30	Coffee and Poster Session (California Ballroom, Hilton)	
4:10	*Thayne Currie*	Debris Disks and the Formation of Terrestrial and Icy Planets
4:30	*Neal Evans (Chair)*	Panel Discussion: Nomenclature for Evolving Disks Calvet, Cieza, Hillenbrand, Merin, Strom, Watson, +TBA
6:00	**NOTE:**	Posters must be removed from California Ballroom; those in International Ballroom can stay up through Thursday

Conference Banquet (Twin Palms Restaurant, Old Town Pasadena)

6:30	Bar opens
7:30	Banquet starts

Thursday, October 30, 2008

Debris Disks

8:00 am	**Coffee** (California Ballroom, Hilton)	
	Plenary session (International Ballroom, Hilton)	
8:30	*John Carpenter*	Debris Disk Census from 5 Myrs to 5 Gyrs
9:20	*Ben Zuckerman*	Planetary Systems Around Close Binary Stars: the Case of the Very Dusty, Sun-like, Spectroscopic Binary BD+20 307
9:40	*Clio Gielen*	Dust Grain Processing in Keplerian Discs Around Post-AGB Binaries
10:00	Coffee and Poster Session (California Ballroom, Hilton)	
10:30	*Mark Wyatt*	Debris Disk Dynamical Theory
11:20	*Torsten Löhne*	How Extrasolar Planetesimals Show Up in Spitzer Data
11:40	*Kate Su*	Diversity of Debris Disk Structures - Combining Resolved Imaging and Spectral Energy Distribution Models
12:00	Lunch and Posters	
1:30	*Karl Stapelfeldt*	Spatially Resolved Debris Disk Studies - Present and Future
2:20	*Holly Maness*	Exploring Planetary Debris Disks at Millimeter Wavelengths: First Detection & Mapping with CARMA
2:40	*Rachel Akeson*	Hot Dust in Debris Disks
3:00	Coffee and Poster Session (California Ballroom, Hilton)	
3:30	*Steve Strom*	Studies of Star Formation and Circumstellar Disks with the Spitzer Warm Mission
4:10	*Ewine van Dishoeck*	Future prospects: Future Science Directions in the Study of Circumstellar Disks
4:50		End of Conference

Day 1 Oral Presentations

Invited Review
Initial Conditions: The Transition from Cores to Disks

Neal Evans
The University of Texas at Austin

The evolution of protostars from infalling envelopes to revealed disks sets the initial conditions for later evolution of the star-disk system. Spitzer was able to detect mid-infrared emission from most Class 0 objects, providing direct evidence for disks and constraining their properties during the early infall phase. Studies of large samples with Spitzer have clarified the timescales for envelope dissipation and provided strong evidence for large variations in accretion rate, with likely consequences for initial disk properties and materials. These may have substantial consequences for later evolution.

Observations of the Earliest Stages of Protostellar Disks

Jes Jørgensen
AIfA, University of Bonn

Circumstellar disks are likely formed in the early, deeply embedded stages in the evolution of young stellar objects. Their properties are related to the physical and chemical structure of the innermost regions of the centrally condensed envelopes surrounding such protostars. I will present the results from a large survey of about 20 Class 0 and I low-mass protostars using high-angular resolution, submillimeter observations from the Submillimeter Array. These observations are highly complementary to Spitzer observations that detect many of these sources for the first time at mid-infrared wavelengths and provide strong constraints on the physical structure on the inner envelopes and the structure of circumstellar disks. Together these observations paint a picture in which disks form early in the evolution of young low-mass stars: the inferred masses of the central disks are comparable for both Class 0 and I objects, which suggests that disks are formed and grow to significant sizes early in the evolution of the protostars. Line observations of the more evolved Class I systems reveal rotational signatures which in turn constrain the central stellar masses and allows us to trace evolution of the mass of the stars, disks and envelopes through these pivotal stages in protostellar evolution. This study will serve as a pathfinder for large-scale surveys, e.g., of large Spitzer-selected samples, once the Atacama Large Millimeter Array (ALMA) is fully operational.

Rainfall from Protostellar Envelopes onto Protoplanetary Disks

Dan Watson
Universitsy of Rochester

Class 0 protostars, the youngest type of young stellar objects, show many signs of rapid development from their initial, spheroidal configurations. They are therefore studied intensively for details of the formation and nature of the dense cores within protostellar envelopes. At millimeter wavelengths, kinematic signatures of envelope collapse have been observed in several such objects. These objects and many more Class 0s also show evidence of strong high-velocity bipolar outflows. The long-sought link between these two flows and the central protostar – the embedded protoplanetary disk – has recently been discovered in observations with the Spitzer Space Telescope's Infrared Spectrograph. We have detected rich emission spectra of water vapor, at wavelengths 20-37 microns, in ten Class 0 objects in the NGC 1333, Orion A and Chamaeleon II clouds. The observations indicate directly the presence of extremely dense, warm gas from regions of Solar-system dimension. Models based upon vigorous infall onto a disk, in the form of a plane-parallel disk-accretion shock, reproduce the observed spectra well. More complex models will enable precise constraints to be placed on the structure and stability of the youngest protoplanetary disks. The observations also show directly that water arrives in protoplanetary disks as a warm vapor rather than ice, thus erasing any chemical signature of this material's interstellar origins.

Invited Review
Disks around Very Young Massive Stellar Objects

Thomas Henning
Max-Planck-Institut fuer Astronomie

Circumstellar disks have been found to be associated with a wide range of young (sub)stellar objects, ranging in mass from brown dwarfs to Herbig Ae/Be stars. They are a natural by-product of the star formation process and important structures for mass and angular momentum transport. Disks in early phases of the build-up of massive stars play a key role in channelling radiation and infalling matter. The search for disks around massive protostellar and young stellar objects remains a challenge because of their distances, locations in complex environments, and the necessity to find the right tracers for their presence. The talk will discuss the different strategies to search for such disks. I will review the observational evidence for disks around massive young stellar objects and discuss their structure and physical properties.

Spitzer Observations of Young Stellar Objects throughout the Milky-Way

Thomas Robitaille
University of St Andrews

In this talk I will present the results of a highly reliable census of ∼20,000 intrinsically red sources selected using Spitzer/GLIMPSE observations of 274 square degrees of the Galactic mid-plane. This census includes over 10,000 young stellar objects - of which a large fraction are likely to be young stars with circumstellar disks - making this the largest sample of Spitzer-selected young stellar objects to date. This census effectively provides a map of star formation throughout the Galactic mid-plane as seen by Spitzer, showing hierarchical clustering, star formation in dark clouds, and possible isolated star formation. Because of the large number of sources in this census, we are able to empirically separate YSOs from AGB stars in a statistical way, and are therefore able to estimate the contamination from AGB stars in Spitzer observations of star formation regions in the Galactic mid-plane.

The Spitzer Legacy Survey of the Cygnus-X Region

Joseph Hora

Harvard-Smithsonian CfA

We describe the status and initial results from the Spitzer Legacy survey of the Cygnus-X region, a massive star formation complex containing the richest known concentration of massive protostars and the largest OB associations within the nearest 2 kpc. This unbiased survey of 24 sq degrees in Cygnus-X with the IRAC and MIPS instruments has the sensitivity to detect young stars to a limit of 0.5 Msun. With this survey we will 1) analyze the evolution of high mass protostars with a large and statistically robust sample at a single distance, 2) study the role of clustering in high mass star formation, 3) study low mass star formation in a massive molecular cloud complex dominated by the energetics of 100 O-stars, 4) assess what fraction of all young low mass stars in the nearest 2 kpc are forming in this one massive complex, and 5) provide an unbiasedsurvey of the region and produce a legacy data set which can be used in conjunction with future studies of this region (e.g., with Herschel and JWST). We are also using the IRS to obtain 5-40 micron spectra of a sample of massive stars that are forming in the Cygnus-X region. The selected sample contains known IRAS/MSX sources and infrared-quiet sources detected in mm-surveys and the deeper Spitzer observations, thus spanning a range of mass and evolutionary stages which will allow us to probe the earliest stages of massive protostars. We will present initial results from the imaging survey and the spectra of the selected massive protostars.

Invited Review
Disk Frequency and Distribution in OB Associations

Tom Megeath
University of Toledo

I will overview Spitzer surveys of nearby OB associations, with an emphasis on surveys of the Orion OB1 association. These surveys show extended distributions of low mass stars, including crowded clusters surrounding massive stars and lower density regions where stars form in relative isolation. I will discuss the influence of these environments on star formation and disk evolution. Of particular interest for disk evolution are the 2-10 Myr stars found in the association but outside the molecular clouds. These stars provide a unique testbed for studying disk evolution and also a fossil record of star formtion in the larger OB association.

Disk masses in the Orion Trapezium Cluster

Jonathan Williams
University of Hawaii

We present the results of a 3 year Submillimeter Array survey to measure the 880 um flux toward 41 protoplanetary disks in the Trapezium Cluster in Orion. The disks are identified from HST observations as silhouettes against the bright nebular background and many show cometary tails due to external photoevaporation by the massive stars. The interferometer resolves individual disks and filters out much of the cloud background. The short wavelength allows the disk dust emission to be measured as an excess over the free-free emission from the ionized cocoons. The resulting disk mass function is shown to be similar to that of Taurus and rho Ophiuchus Class II disks but lacks disks more massive than 0.03 Msun. We show that this is consistent with models of external photoevaporation in which the outer disk is rapidly eroded but inner regions, at radii $<$ 50 AU, survive and have enough material to form planetary systems on the scale of our own.

Spitzer and X-ray Observations of Star Forming Regions

Scott Wolk
Harvard-Smithsonian CfA

We examine the properties of several embedded clusters within 2 kpc using data the Spitzer Space Telescope supplemented by data from theXMM-Newton and Chandra X-ray observatories. The clouds range from massive star forming regions - RCW38, RCW108, through large complexes (e.g. L1641) to smaller clusters (e.g. LkHa 101 IRAS20050). We use surveys of entire molecular clouds to understand the range and distribution of cluster membership, size, and surface density. The data demonstrate clearly that there is a continuum of star-forming environments, from relative isolation to dense clusters. Using the combined Spitzer and X-ray data allows a very accurate assessment of cluster size. In L1641, we estimate total number of Class III objects to be as high as 1400. Combined with the Spitzer identified sources we determine that there are nearly 2000 PMS stars south of the ONC. In other regions, we have detected differences in the spatial distributions of Class II and Class III objects (a.k.a. classical and naked T Tauri stars). Comparison of the class fraction as a function of cluster age is crucial to understanding disk evolution. We are performing detailed X-ray analysis of objects identified via Spitzer data as transition disks. These analysis allow us to start the process of understanding the high energy environment in this crucial planetbuilding stage.

Brown Dwarf Disks in the Spitzer Era

Aleks Scholz
SUPA, University of St. Andrews

Young brown dwarfs share many similarities with T Tauri stars. Specifically, many of them exhibit excess emission at infrared and submm wavelengths, indicating the presence of dusty disks. Investigating the properties and evolution of these disks by analyzing their SEDs is a useful probe of brown dwarf origins, and additionally allows us to study the processes of grain and planetesimal growth in an extreme case, constraining the efficiency and universality of planet formation. Over the last few years, sensitive observations with Spitzer have dramatically improved out knowledge about substellar disks. Using Spitzer in combination with sensitive submm/mm observations, we have obtained strong constraints on masses, radii, lifetimes, and evolution of brown dwarf disks. Furthermore, Spitzer has made it possible to explore disks down to object masses of 5-10M$_{jup}$ - at the very bottom of the Initial Mass Function. In this talk, I will provide a comprehensive, up to date picture of disks in the very low mass regime. I will summarize the available observational constraints and point out implications for star and planet formation theory.

Invited Review
Disks in Nearby Low Mass Star-forming Regions

Lori Allen
Harvard-Smithsonian CfA

I will review results on disks in nearby, low-mass star forming regions from c2d, Gould Belt, various GTO and GO surveys. Using these statistically robust samples, I will examine disk frequencies and timescales for YSO evolutionary stages. I will examine the correspondence of evolutionary stage with age (as best we can determine), and consider the observational evidence for age spreads among disk-bearing stars. I will summarize searches for disks around brown dwarfs and ask whether central object mass strongly affects disk frequencies or evolution.

What Spitzer Missed: New Members of Lupus 3 that Don't Boast Their Youth

Fernando Comeron
European Southern Observatory

Spitzer surveys of star forming regions have produced the most complete census of their young stellar and substellar content available to date, thanks to their sensitivity to the emission of circumstellar dust heated to a broad range of temperatures. The majority of members already known thanks to other signatures of youth before the Spitzer era have been recovered by Spitzer based on color-color criteria, which in turn have revealed large numbers of previously unknown members. It is worth wondering therefore if there may be any remaining members unknown, undetected by any of the techniques based on the various signatures of youth usually displayed by members of star forming regions. We present here the results of a survey of the Lupus 1, 3, and 4 clouds that was conceived to provide ground-based visible/red imaging in support to the Spitzer "Cores to Disks" Legacy Program and that, combined with 2MASS photometry, allows us to identify late-type members of those star forming regions based solely on their photospheric spectral energy distributions. Our survey is thus especially well suited to the detection of low-mass stars and brown dwarfs whose circumstellar emission is either too faint to be detected by Spitzer, or altogether absent. The results reveal a significant number of objects with estimated temperatures generally below 3000 K, and visible to near-infrared spectral energy distributions well consistent with membership in Lupus. We present statistical arguments that demonstrate that confusion with either foreground or background contamination is effectively ruled out. The existence of this elusive population suggests that a non-negligible fraction of low mass stars and brown dwarfs manage to reduce their signatures of youth associated with accretion or with the presence of dusty disks to undetectable levels within the first few million years of their lives.

Day 1 Topical Posters

California Ballroom, Sunday through Wednesday

Poster #1: Infrared and Submillimeter Observations of CB130-3

Hyo Jeong Kim
University of Texas at Austin

This paper presents a study about a young stellar object in CB130-3, which has been observed by the Spitzer Space Telescope for the first time. The Spitzer and ground-based telescopes have observed CB130-3 in the infrared and the submillimeter regions. We present the photometry data from 3.6 micron to 850 micron, and use these data to constrain the radiative transfer modeling. The internal luminosity of the source is $L_{int} \sim 0.15 L_{\odot}$, which is a low value for a young star. We also present the molecular line observation data, and perform Monte Carlo simulation for the chemical modeling to reveal the chemical properties of CB130-3.

Poster #2: Spitzer Observations of the Taurus Molecular Cloud: Old and New YSOs

Luisa Rebull
SSC/IPAC/JPL

Taurus hosts a distributed mode of low-mass star formation that has proven particularly amenable to observational and theoretical study. In 2005-7, our team mapped the central 44 square degrees of the main Taurus cloud using the IRAC and MIPS cameras on the Spitzer Space Telescope. These images form the largest contiguous Spitzer map of a single star-forming region (and any region outside the galactic plane). The Spitzer survey is a central and crucial part of a multiwavelength study of the Taurus cloud complex that we have performed using XMM, CFHT, and the Sloan Digital Sky Survey. The photometry data points from Spitzer allow us to characterize the circumstellar environment of each object. In conjunction with the rest of the surveys (in the regions where all surveys overlap), we can construct spectral energy distributions (in the best cases) from 0.212 to 160 microns for the known population. By comparison to the color distributions of the known Taurus members, we can look for new members among the rest of the detected objects. In this contribution, we will present early results for the full SEDs and colors of known members, and a first look at our new candidate members.

Poster #3: The Role of Dust Associated with Young O Stars

Ed Churchwell
University of Wisconsin

Spitzer images toward massive star formation regions show that dust is the main contributor to the emission at MIR wavelengths. The presence of dust in hot ionized HII regions has several important consequences. In this poster, I will discuss the lifetime of dust in HII regions as a function of size and proximity to the central star; cooling by dust, MIR dust emission mechanisms near hot stars,and the types of MIR bubbles that result from stars with different luminosities.

Poster #4: MWC 297: A Young High-mass Star Rotating at Critical Velocity

Bram Acke
KULeuven, Belgium

MWC 297 is a nearby high-mass young star of spectral type B1.5V. The central star is attenuated by 8 mag in the optical and has a high projected rotational velocity of 350 km/s. We argue that the attenuation towards the system is interstellar and most likely due to remnants of the parental cloud. We have probed the circumstellar matter of MWC 297 with spectrally resolved interferometric measurements in the near- (1.6-2.5 micron) and mid-infrared (8-13 micron). The data have allowed us to construct a color image of the flat circumstellar disk. We find that most of the emission at these wavelengths - including the 10 micron silicate emission - emanates from a very compact region around the star (<1.5 AU), well within the dust destruction radius. Moreover, the almost pole-on view on the system (i < 40 deg) implies that the high projected rotational velocity corresponds to an actual velocity which exceeds the critical velocity of the star. Our discovery shows that stars can achieve critical rotation at birth. We discuss the impact of this result in terms of high-mass star formation and main-sequence evolution of classical Be stars.

Poster #5: Enrichment of the Dust-to-Gas Mass Ratio in Bondi/Jeans Accretion/Cloud Systems

Paul Bellan
Caltech

A cloud-accretion model has been developed having both an inner Bondi-type regime where gas pressure is balanced by the gravity of a star and an outer Jeans-type regime where gas pressure is balanced by gas self-gravity. High-velocity dust impinging on this cloud piles up due to having a different velocity profile than gas. This pile-up causes substantial enrichment of the dust-to-gas ratio above the 1% ISM level. An example where the dust-to-gas mass ratio is enriched to 20% will be presented (see ApJ 678, p.1099-1108, 2008).

Poster #6: The Fate of Discs: Forming Low-mass Objects by Disc Fragmentation

Dimitris Stamatellos
Cardiff University

We suggest that stars like the Sun should sometimes form with massive (a few 0.1 Msun), extended (a few hundred AU) discs, and we show by means of radiative hydrodynamic simulations that the outer parts (>100 AU) of such discs are likely to fragment on a dynamical time-scale, forming low-mass objects: principally brown dwarfs, but also low-mass hydrogen-burning stars and planetary-mass objects. We will present the predictions of this model on the mass distribution of the objects formed, their orbital properties (semi-major axis, eccentricity, orbital plane), and their binary properties, and we will compare these properties with the observed properties of low-mass objects. We will show that the formation of low-mass objects by disc fragmentation explains the brown dwarf desert and the binary properties of low-mass objects. Finally, we shall discuss the possibility of observing such discs with current and future observing facilities.

Poster #7: Herschel Mission Update and Overview of Key Programmes on Circumstellar Disks

Göran Pilbratt
ESA

The Herschel Space Observatory is the next observatory mission in the European Space Agency (ESA) science programme. Herschel will carry a 3.5 metre diameter passively cooled telescope. The science payload complement - two cameras/medium resolution spectrometers (PACS and SPIRE) and a very high resolution heterodyne spectrometer (HIFI) - will be housed in a superfluid helium cryostat. Herschel will perform imaging photometry and spectroscopy in the far infrared and submillimetre part of the spectrum, covering approximately the 55-672 micron range. The key science objectives include star formation and circumstellar disks as one of the drvvers. Once operational in orbit around L2 after a launch in early 2009 and followed by an early operations period of 6 months, Herschel will offer a minimum of 3 years of routine science observations. Nominally ~20,000 hours will be available for astronomy, 32% is guaranteed time and the remainder is open to the general astronomical community through a standard competitive proposal procedure. The time allocation for both GT and OT Key Programmes has been concluded. I will summarise the accepted Key Programmes with an emphasis on circumstellar disk programmes. Finally I will mention future observing opportunities.

Poster #8: Intensive Mass Loss from an Evolved Disk in the Sigma Ori Cluster.

Elisabetta Rigliaco
Arcetri Observatory

We present a study of the accretion properties of the object SO587, a 0.3 M_{sun} star in the sigma Ori cluster which is surrounded by an evolved disk (Hernandez et al.,2007). The Hα profile is rather narrow and single-peaked; the accretion rate derived from the U-Band excess emission is low (of the order of about 10^{-10} M_{sun}). However the optical spectrum of this star shows strong emission in the forbidden lines of NII, OI and SII (Zapatero-Osorio et al.,2002; Sacco et al.,2008). If these lines are interpreted as coming from a wind,they correspond to a mass loss rate of about 10^{-9} M_{sun}/yr,i.e. to a very low ratio M_{acc}/M_{wind}. In this poster we explore this as well as other scenarios, and discuss their implications.

Poster #9: Polycyclic Aromatic Hydrocarbon (PAH) Emission from a Young, Embedded Protostar in NGC 2264

Achim Tappe
Harvard-Smithsonian CfA

We present a Spitzer IRS spectrum toward a deeply embedded (A_V ~17 mag) protostar in NGC 2264 featuring strong PAH emission. The mid-IR continuum emission peaks longward of 70 micron and shows a strong 15.2 micron CO2 ice feature, suggesting that the source still retains an envelope and presumably is a Class I object. The observed PAH emission originates less than 1000 AU from the star, and is most likely associated with its accretion disk or inner envelope. A preliminary analysis of the PAH bands shows that the PAH molecules are very small and ionized, implying the presence of a strong UV radiation field and a possible connection with the strong observed X-ray emission from the protostar.

Poster #10: The Disk Population of North America and Pelican Nebulae Observed by IRAC and MIPS.

Sylvain Guieu
SSC

Much of our current knowledge regarding star-forming patterns and circumstaller disk evolution derives from study of molecular cloud complexes within a few hundred parsecs of the sun. Among this group are a large number of lower-mass clouds such as Taurus and, more infrequent, are dense clouds like the Orion nebula cluster which the prototypical high-mass and high density star forming region. These nearby cloud complexes has served as our primary empirical guide to understanding the formation and early evolution of stars. However, they provide snapshot of just extrema of the star-formation process. That is important that we study more than just the nearest examples of the extrema of star formations models. The nearby (600 pc) North America and Pelican nebula are such mixed-mode star formation regions. We have conducted a large infrared imaging with the SPITZER telescope on these regions. 5 deg^2 has been observed with IRAC and 6.2 deg^2 with MIPS. We possess as well BV I CCD imaging for the $\sim 2 \times 2$ degrees region encompassed by the complex. Thanks to IRAC and 2MASS data we found more than 1000 sources with infrared excess characteristic of young stars objects (YSOs). We have plotted the SED of each YSO from optical (when available) to MIPS 24μm and classified them to usual class III / II / Flat and I. In this contribution we discuss proportions of different YSO classes, compare them to other star forming regions, and discuss implication on cloud properties. Moreover, we discuss about the clustered spatial distribution of YSOs among the cloud and discuss the degree of cauterization function to YSO's classes.

Poster #11: Probes of Protostellar Structure with Spitzer

John Tobin
University of Michigan

We present initial results from a Spitzer archival study of protostellar structure. We have selected 30 protostars within 450pc which exhibit resolved scattered light cavities in IRAC observations. Protostellar structure provides the initial conditions of disk formation. Specifically, the compositon of the dusty envelope and its infall rate influence the resultant properties of the circumstellar disk. We employ a Monte Carlo radiative transfer code to model the envelope structure and SED as viewed in scattered light cavities and thermal emission from NIR to millimeter wavelengths. In addition to the constraints given by radiative transfer modeling, we directly probe the envelope structure observed in absorption against background ISM emission at 8.0 microns. Some envelopes exhibit an approximately spherical structure, while most have complicated morphologies including flattened geometries. We have used these data to construct optical depth maps of these envelopes and calculated their masses based on tabulated opacities and distances.

Poster #12: Disks Around Intermediate Mass Stars in IC 1805

Sidney Wolff
NOAO

Authors: L. M. Rebull, IPAC S. E. Strom, NOAO S. C. Wolff, NOAO We present the results of a study aimed at establishing the frequency and characteristics of circumstellar accretion disks surrounding intermediate mass ($\sim$2-6 solar masses) stars in the rich, young cluster (t $\sim$ 1-2 Myr) IC 1805. Our dataset comprises optical (UBV), near-IR (2MASS), IRAC, and MIPS photometry and optical spectroscopy, which together enable identifying 218 cluster members, placing them in an HR diagram, determining their spectral energy distributions, and characterizing disk properties from the magnitude and shape of the excess infrared emission above photospheric levels. Our analysis suggests (a) that analogs of Herbig Ae/Be stars (stars surrounded by accretion disks whose dust component extends inward to the dust destruction radius) are rare ($\sim$3% of our sample); and (b) there are a significant ($\sim$10% of the sample) number of stars (of spectral types ranging from B through early F) that exhibit infrared excesses, especially in the two longer IRAC bands, that seem best explained by assuming that they arise either from gaseous inner disks analogous to those that surround rapidly rotating Be stars, and similar to the Class III Herbig Ae/Be stars discussed by Hillenbrand et al. (1992) or from disks with inner holes. We discuss alternative explanations for these latter objects and conclude that they may be analogs of the so-called transition objects found among solar-type PMS stars (objects surrounded by accretion disks that are nearly dust-free in their inner regions, but dust rich outward of the dust-free zone).

Poster #13: A Spectral Inventory of Massive YSOs in the LMC

Jonathan Seale
University of Illinois

We obtain, present, and categorize Spitzer IRS spectra of 294 objects in the Large Magellanic Cloud (LMC) to create the largest and most complete catalog of massive young stellar objects (YSOs) in the LMC. Target sources were identified from infrared photometry and multi-wavelength images indicative of young, massive stars highly enshrouded in their natal gas and dust. Several objects have been spectroscopically identified as non-YSOs and have features similar to more evolved stars such as red supergiants (RSG), asymptotic giant branch (AGB) and post-AGB stars. Our sample of a total of 294 sources primarily consists of 277 objects (94%) we classify as YSOs. The remaining sources are comprised of 7 C-rich evolved sources, 8 sources dominated by broad silicate emission, and 1 multiple broad emission feature-dominated source. The YSOs show a range of spectral features including polycyclic aromatic hydrocarbon (PAH) emission, deep silicate absorption, fine structure lines, and ice absorption features. Based upon the relative strengths of these features, we have further classified the YSOs into several distinct categories using the widely-used statistical procedure known as principal component analysis (PCA). We propose that these categories represent distinct evolutionary stages of a massive YSO's formation. Using our catalog we put statistical constraints on the relative evolutionary timescale of processes involved in massive star formation. We conclude that massive pre-main sequence stars spend a majority (possibly as high as 90%) of their massive, embedded lives emitting in the UV. We additionally conclude that massive YSOs will ionize a compact HII region approximately half-way though their formation.

Poster #14: Dusty Cometary Tails on a Stellar Scale

Xavier Koenig
Harvard University

Recent observations of star forming regions with Spitzer at 24 microns have shown the effects of massive stars on nearby disks, as manifested by large-scale cometary objects that glow in the mid-infrared. We present results for four such objects in the W5 star forming region. We model the objects as circumstellar disks in which dust is blown out by the radiation pressure from nearby O stars, after the gas has been removed by photoevaporation. We discuss the implications of this phenomenon for disk evolution and planet formation in the clustered environment.

Poster #15: Where is the Driving Source for HH 168?

Joel Green
University of Rochester

Herbig Haro objects are small emission nebulae that signify the interaction between both broad and collimated outflows from young stellar objects and the ambient molecular cloud material. GGD 37 is actually suspected to be an amalgamation of at least two superposed flows (including HH 168) traveling in different directions on the sky. Weaker shocks (less than $\sim$ 10000 K) excite the molecular hydrogen into various rotational states detectable at IRS wavelengths, while strong shocks completely destroy the molecules and illuminate the ions. The Infrared Spectrograph on board Spitzer has enabled us to gather spatial information on a number of higher excitation species, and place greater constraints on the flows, allowing us to separate them chemically. How does the instability of driving sources of Herbig Haro jets affect their surrounding medium? By studying the pre-and post-shock gas, we can determine whether outflows from young stars have greater clumping or dispersive effects on their environment. Do outflows trigger or suppress star formation in the neighborhood? And finally, new observations from the IRS shed new light on the question: exactly where is the protostar that is driving HH 168?

Poster #16: A Correlation between Rotation Period and Disk Presence in the ONC and NGC 2264

Nairn Baliber
LCOGT and UCSB

Observations of PMS star rotation periods reveal slow rotators in young clusters of various ages, indicating that angular momentum is somehow removed from these rotating masses as they contract onto the main sequence. Using the disk identification capability of Spitzer Space Telescope data, we have studied the angular momentum history of pre-main-sequence (PMS) stars in the young Orion Nebula Cluster and NGC 2264. Once mass effects and sensitivity biases are removed, an unambiguous correlation between PMS star rotation periods and the presence of a circumstellar disk for stars with spectral type M2 and earlier is revealed, providing clear evidence that star-disk interaction regulates PMS star angular momentum. Because Spitzer data allows the populations of stars with and without disks to be separated accurately, a quantitative analysis of the angular momentum history of these clusters is now underway using Monte Carlo simulations. Parameters such as disk release timescales, angular momentum transfer efficiency, and fractions of stars released by their disks as a function of time can be constrained. We present our observational results, preliminary results from our ongoing numerical simulations, and discuss future work to study the same effect in stars of spectral type M3 and later in NGC 2264 with Spitzer Cycle 5 data.

Poster #17: X-Ray Observations of Star Formation in Serpens

Joanna Brown
Max Planck Institut fur Extraterrestrische Physik

We present XMM X-ray observations of Serpens with >150 young stars detected in two EPIC fields. Spitzer infrared maps of this region revealed dense dust and numerous previously unknown pre-main sequence (PMS) stars, diverse in both mass and age. Comparison of the infrared disk and X-ray coronal properties allows detailed characterization of the individual stars and investigation of evolutionary trends in different regions. Young stars are strong X-ray emitters throughout their PMS evolution, from embedded protostars to older dust-free (and hence infrared-faint) PMS stars. X-ray emission provides an excellent method of tracing the entire PMS population and investigating the star formation histories of these regions and the processes controlling the fragmentation and formation of stars.

Poster #18: X-ray and Infrared Observations of the IC 5146 Dark Cloud and the FU Orionis Star Elias 1-12

Stephen Skinner
Univ. of Colorado

The bright B1V star BD +46 3474 illuminates the Cocoon Nebula (IC 5146). Studies of this spectacular nebula have a long historical record dating back to Dreyer (1895) and Wolf (1904). More recent work has uncovered at least one hundred faint T Tauri stars clustered around BD +46 3474 with a median age of about 1 Myr (Herbig & Dahm 2002). Extending more than two degrees westward from BD +46 3474 is a region of high obscuration known as the IC 5146 dark cloud. Near-infrared surveys have revealed a large population of heavily-extincted stars in the cloud, and submillimeter studies have detected dense cores that may be prestellar. We present results of an XMM-Newton X-ray observation of the dark cloud centered on the rapidly-accreting FU Ori-type star Elias 1-12 (= V1735 Cyg). Its X-ray emission is much harder than expected for an accretion shock and other processes besides accretion must underlie its X-ray production. We also make use of archived Spitzer and 2MASS images to identify other heavily-obscured X-ray sources near Elias 1-12.

Poster #19: The Circumstellar Environments of B[e] Supergiants in the Magellanic Clouds: Evidence for Dusty Disks

Raghvendra Sahai
JPL / Caltech

The study of massive stars is central to many areas of astrophysics, including the study of supernovae, nucleosynthesis, galactic evolution, and reionisation of the early universe. One of the more extreme classes of massive stars is that of early-type, emission-line (B[e]) supergiants and hypergiants. These objects represent a late phase in the core-burning lifetimes of very massive stars, and include amongst them the most luminous stars known. As a consequence of the small line-of-sight extinction toward the Magellanic Clouds (MCs), two-thirds of all known B[e] supergiants and hypergiants are found in the LMC and SMC. We present preliminary results from a program of IRS spectroscopy to investigate the circumstellar environments of confirmed and candidate B[e] supergiants in the MCs. More than half of the dozen or so objects observed display near- to far-IR spectral characteristics (relatively flat infrared spectral energy distributions and emission features characteristic of silicate dust and, in a few cases, PAHs) indicating the presence of circumstellar disks. Most of the objects with dusty disks are located near compact HII regions or in the vicinities of massive young star clusters, indicating ages of at most afew Myr. These results suggest that most B[e] supergiants represent scaled-up analogs to intermediate-mass, pre-main sequence (Herbig Ae/Be) star-disk systems. The few candidate objects that do not display disk-like IR spectral energy distributions are all associated with compact HII regions; these objects are probably massive pre-MS or zero-age MS (as opposed to B[e] supergiant) stars. We use models of passive, irradiated disks to fit the observed spectra for specific objects that display disk-like spectra, in order to constrain disk mass and radial density structure.

Poster #20: The YSO Population of the Auriga Molecular Cloud: Results from the Gould Belt Legacy Survey

Brenda Matthews
Herzberg Institute of Astrophysics

We present a census of young stellar objects within the relatively unstudied Auriga molecular cloud, part of the Gould Belt Legacy Survey. We find that the Auriga cloud has a sizeable population of YSOs (many of which lie in an aggregate in close proximity to LkHa101), of which roughly half are in the Class II phase with evidence of circumstellar disks. We also discuss the overall distribution of YSO candidates in Auriga based on extensive MIPS mapping of the cloud. We compare the YSO population and distribution in Auriga to other nearby star-forming clouds. Our results reveal that Auriga has undergone active star formation very recently.

Poster #21: AKARI Near-Infrared Spectroscopy: Detection of H2O and CO2 Ices toward Young Stellar Objects in the Large Magellanic Cloud

Takashi Shimonishi
University of Tokyo

We present the results of near-infrared (NIR) spectroscopic observations of Young Stellar Objects (YSOs) in the Large Magellanic Cloud with the Infrared Camera (IRC) on board AKARI satellite. Properties of extragalactic Young Stellar Objects (YSOs) provide us important information on the understanding of the diversity of YSOs in different galactic environments. An infrared spectrum of YSOs shows absorption features of various ices which are thought to be an important reservoir of heavy elements and complex molecules in the circumstellar environments of YSOs. We have performed a low resolution (R $\sim$ 20) NIR spectroscopic survey of the LMC with the IRC on board AKARI. We detected absorption features of the H2O ice 3.05um and the CO2 ice 4.27um stretching mode toward seven massive YSOs. These samples are included in the recent YSO candidates catalog based on Spitzer SAGE photometric database and for the first time spectroscopically confirmed to be YSOs by the present study. This is the first detection of the 4.27um stretching mode of CO2 ice toward extragalactic YSOs. Studying the compositions of ices as functions of physical environments is crucial to understand the chemical evolution in circumstellar environments of YSOs. We evaluated the column densities of the ices toward these seven YSOs and derived the CO2/H2O ratio to be 0.59+-0.31. This is clearly higher than that seen in Galactic massive YSOs (0.17+-0.03). We suggest that the strong ultraviolet radiation field and/or the high dust temperature in the LMC may be responsible for the observed high CO2 ice abundance. We report the detail of the present study in our presentation. The studies of the ices and the extragalactic YSOs have been conducted actively by Spitzer. The present NIR spectroscopic study by AKARI is expected to play an important and complementary role in these areas.

Poster #22: Disks around Young Brown Dwarfs

Lucia Adame
Instituto de Astronomia, UNAM

We modify the computational codes developed by D'Alessio and colaborators to obtain the vertical and radial structure of an accretion disk irradiated by a young substellar object, the circumsubstellar disk; we discuss its structure and the possible differences between it and its massive counterparts (the circumstellar disk). A set of models and their corresponding SED, ranging several mass accretion rates, substellar effective temperature, and alpha-viscosity parameter, are constructed; with that, and using previously published IRAC data, we study the innermost region of the circunsubstellar accretion disks in the Taurus region. The median SED of Taurus for stellar/substellar objects with spectral types between M6 and M7.75 is obtained.

Poster #23: The Evolution of Accreting Young Massive Objects

Harold Yorke
JPL / Caltech

Most massive stars form via accretion through an accretion disk, starting with a low mass object (a few Jupiter masses) in hydrostatic equilibrium and gradually growing in mass as material accretes onto it. The time scale for this process is relatively short, typically less than a few 100,000 years, implying mass accretion rates in excess of 10^{-4} solar masses per year for stars of 20 solar masses and higher. Accreting protostars evolve differently from non-accreting protostars. In particular, stellar radii well in excess of 100 solar radii are possible.

Poster #24: A MIPS View of Dense Cores and Embedded Sources in the Taurus Spitzer Legacy Survey

Susan Terebey
Cal State LA

We analyze the 160 micron emission in the 44 sq deg Taurus Spitzer Legacy Survey to produce a mosaic of the cold dust distribution. The analysis shows there are two main emission components: the extended cold cloud at 14.2K, and knotty filaments of cold cores at $\sim$10K. The distribution of 160 micron cold cores is similar to the 2mass extinction map, but has higher $1'$ spatial resolution. We further compare the distribution of cold cores with YSOs that have strong disk emission at 70 micron. In this sample 90 percent of class I sources and 55 percent of class II sources are spatially coincident with a cold core. However, most cold cores in Taurus are starless.

Poster #25: Hierarchical Structure in Nearby Star-Forming Clouds

Robert Gutermuth
FCAD/Smith College

I will present new results from a Spitzer survey of the active star-forming molecular clouds, Cepheus OB3 and Monoceros R2. These clouds are relatively nearby (730-830 pc), yet are forming intermediate and high mass stars in addition to many hundreds of low mass stars. As such, these clouds represent a complementary star-forming environment to the nearby (<400pc) clouds surveyed as part of the c2d, Gould Belt, and Taurus Legacy surveys, where only low mass star formation can be found. The CepOB3 and MonR2 clouds both have several clusters of forming young stellar objects, but the extent of lower number density star formation in these clouds has been largely uncharacterized. I will show a new hierarchical characterization of the spatial distribution of all Spitzer-identified YSOs in these clouds. With such a treatment, we can examine in detail distributed star formation within these clouds and compare it to the high density environments of their embedded clusters.

Poster #26: Line of Sight Radiative Transfer Analysis of B68 and TMC1-C

Christopher De Vries
CSU Stanislaus

We present the results of an analysis of CS J=2-1 and N2H+ J=1-0 spectral line observations of B68 and TMC1-C using best fit analytic radiative transfer models to simulate the emission along each line of sight. The radiative transfer model is designed to simulate self-absorbed asymmetric line profiles by assuming that there is an excitation temperature gradient along each line of sight and that there is a uniform infall or outflow velocity which results in a blue or red asymmetric line profile. Observation of optically thin isotopologues of CS and N2H+ indicate that the molecular line profiles in B68 and TMC1-C are self-absorbed, making these analytic line of sight models appropriate tools to analyze observations of these regions. Analysis of each line of sight using the analytic radiative transfer model yield maps of the five parameters that make up the model: line of sight velocity, infall speed, optical depth, peak excitation temperature, and line width. By mapping these parameters of the fit to the line profiles, we are able to find regions which have distinct spectral features, which may indicate a kinematically distinct regions of the larger cloud. Analysis of B68 and TMC1-C indicates that these clouds are complex regions which may both contain regions of infall, outflow, high optical depth, low optical depth, high peak excitation, and low peak excitation temperatures within the same core. In both clouds the region with the highest optical depth does not match the region with the highest excitation temperature, indicating that these regions should not be thought of as spherical dense central peaks, but rather complex dynamical structures. We identify spectrally unique signatures in each cloud and attempt to build a coherent picture of the physical state and dynamical processes in these star-forming

regions.

Poster #27: A Spitzer IRAC and MIPS Survey of 3 Dark Clouds

Babar Ali
NHSC/IPAC/Caltech

The Spitzer legacy program c2d results suggest that the so-called "starless" cores may not necessarily be starless. Motivated by these results, we have undertaken a study of the 3 dark cores that are classified as starless, Lynds opacity class 6 and have thus far escaped attention from observers (in that only 2-3 citations are found via literature searches). I present preliminary results from our investigations for signs of star-formation in these clouds using Spitzer's IRAC and MIPS observations.

Poster #28: Star Formation Research and the NASA/IPAC Infrared Science Archive (IRSA)

Anastasia Alexov
Caltech - IPAC/IRSA

IRSA currently curates and serves data from 24 projects and missions, including 120 source catalogs, 48 image data collections, and seven spectral data sets. This paper highlights the data and services of importance to star formation researchers. IRSA hosts science products from the IRAS, 2MASS, and MSX surveys, the Spitzer Legacy team surveys GLIMPSE, MIPSGAL and SAGE, the pointed observations of the Spitzer Legacy programs C2D and FEPS, and the SWAS mission. IRSA is also interoperable with the Spitzer archive. IRSA has recently enhanced its data access services to support input of source lists, and scripts to support bulk download of data. It will soon complete the definition of "program-friendly interfaces" (including those that comply with VO-standards) that will automate access to all its data through queries embedded in programs and scripts. IRSA offers unique tools that support extraction of optimized science content of its data sets. The IRAS Scan Processing and Integration Tool ("Scanpi"), which computes weighted average fluxes of 1-dimensional (in-scan) IRAS raw survey data, has been modernized to give the user insight into the processing steps. The Montage image mosaic engine, available for download, computes science-grade mosaics that preserve the calibration and astrometric fidelity of the input images. It has been used by Spitzer Legacy teams in generating their science products, and it powers an on-request mosaic service accessible from a simple web form. IRSA will deliver new data sets applicable to star formation in the next four years. In mid-2011, it will assume responsibility for the long-term Spitzer archive, and will serve data from all the Spitzer Legacy Enhanced Products. It will host the archive for WISE, and will provide access to science products from the Herschel and Planck missions.

Day 2 Oral Presentations

Invited Review
Issues in Protoplanetary Disk Modeling

Nuria Calvet
Univ. of Michigan

Observations from the Spitzer space telescope have revolutionized the field of protoplanetary disks and planet formation. Analysis of the SEDs provided by Spitzer, together with accretion indicators and images, have provided unprecedented information on the degree of dust growth and settling in these disks. Observations of disks in populations with ages in the range when planets are expected to form show evolutionary effects that are consistent with expectations of dust evolution theories. However, large uncertainties remain in the actual mechanisms and time scales of these processes. I discuss what we have learned from SED studies, what we still need to learn, and possibilities for further progress.

The Formation and Evolution of Protostellar Disks

Shantanu Basu
University of Western Ontario

We have studied numerically the self-consistent formation (from cloud core collapse) and evolution of disks around young stellar objects. The global evolution of the disk is followed for several million years after its formation. Calculations of such large dynamic range in space and time are made possible by use of the thin-disk approximation, and are not yet possible using fully three-dimensional simulations. We find that the disk evolution has an initial burst phase of accretion, during which the disk accretion rate is usually low ($10^{-8} - 10^{-7}$ Msun/yr) but is punctuated by brief bursts of high accretion rate ($\sim 10^{-4}$ Msun/yr). Later on, during the T Tauri phase, the disks settle into a self-regulated state, with low-amplitude nonaxisymmetric density perturbations persisting for at least several million years. The global effect of gravitational torques due to these perturbations is to produce disk accretion rates that are of the correct magnitude to explain observed T Tauri star accretion rates. Our models yields a correlation between accretion rate Mdot and stellar mass Mstar that has a best fit Mdot $\sim$ Mstar$^{1.7}$, in good agreement with a now widely-observed correlation.

Understanding Spitzer Observations of Protostellar Disks Using 3-D MHD Calculations

Neal Turner
JPL / Caltech

Magnetic forces drive the accretion flows in T Tauri disks and produce the stirring that enables dust to remain suspended in disk atmospheres for millions of years. I will discuss 3-D MHD calculations properly treating the coupling of the gas to the magnetic fields, demonstrating that atmospheric turbulence and heating coexist with a cold laminar midplane flow that provides a favorable environment for the growth of planetesimals. I will show how the calculations can be used to interpret Spitzer measurements of the mid-infrared dust bands and the spectral lines formed in the warm disk atmosphere, and outline how the same physical processes may lead naturally to the properties of the transitional disks. This work was carried out in collaboration with T. Sano, J. Carr and J. Najita at the Jet Propulsion Laboratory, California Institute of Technology with support from the JPL Research & Technology Development and NASA Solar Systems Origins program.

Invited Review
The Observed Diversity of YSO Disk Properties

Bruno Merin
European Space Agency

The Spitzer data, with their wavelength coverage, offer an exceptional tool for studying the status and evolution of the inner zones in the disks around young stars (1-30 AU), where planets eventually form. We present the results on disk evolution from the 'Cores to Disks' (c2d) Spitzer Legacy Program, which mapped five nearby star-forming regions from 3 to 70 microns and provides a large and magnitude-limited sample of 700 protoplanetary disks with ages smaller than 10 Myr. This data set is analyzed with the use of a new two-dimensional classification scheme which provides information on the detailed structure of the inner disks, such as grain growth, dust settling, dust depletion and/or presence of inner holes. A statistical description of the different types of disks and their corresponding time-scales is presented. Finally, the characteristics and incidence of the cold or transitional disks (disks with inner holes with the size of the Solar System) in these observations is studied and compared statistically with the properties of the remaining disk sample in the same star-forming regions to search for conditions favorable for early inner disk evolution and possibly efficient planet formation.

IRS Detections of Water Vapor in Protoplanetary Disks

Colette Salyk

Caltech

Salyk, C., Blake, G. A., Pontoppidan, K. M., Lahuis, F., van Dishoeck, E. F., Evans, N. J., II. Recent Spitzer InfraRed Spectrograph (IRS) detections of water and organic molecules in protoplanetary disks (Carr & Najita 2008, Salyk et al. 2008) represent a turning point in the study of the physical and chemical development of terrestrial planet-forming regions. Here we present Spitzer-IRS spectra obtained from the "cores to disks" (c2d) Legacy program, which demonstrate a high detection rate for hot (T$\sim$1000 K) water vapor emission lines in the 10-20 μm region covered by the ShortHi module. We also present complementary ground-based L-band ($\sim$3 μm) observations obtained with NIRSPEC (R$\sim$25,000) on the Keck II telescope and CRIRES (R$\sim$100,000) at the VLT at sufficiently high spectral resolution to measure the line shapes and thus constrain the emitting locations in the disks. Preliminary results suggest a variety ofmolecular abundance ratios, which may indicate differences in disk evolutionary states, or intrinsic differences between sources. We explore and present these possibilities and other characteristics of this rich sample. Finally, we discuss these results in the context of ongoing GO-5 IRS observations designed to span an expansive range in disk activity and physical state at high S/N (program PID#50641, J. Carr, Principal Investigator).

High Temperature Silica in Protoplanetary Disks

William Forrest
University of Rochester

Silica is identified in the spectra of protplanetary accretion disks through its prominent emission features at 9.1, 12.6, and 20 microns. Silica is largely absent from the ISM (and spectra of many protoplanetary disks), so it must have been produced locally. Various polymorphs of silica are possible, each has a distinctive infrared spectrum. We fit the spectra of five T Tauri stars from the Taurus, Ophiuchus, and Chamaeleon clouds which show prominent silica emission features in high quality IRS spectra from Spitzer. We developed a simple, 2 temperature, "reversing layer" physical model to analyze the emission features arising from the optically thin, superheated upper layers of accretion disks. Our models include emission from small and large amorphous silicate grains, small forsterite and enstatite grains, and small silica grains (alpha and beta quartz, amorphous quartz, and annealed silica). In every case, the best fit was given by the "annealed silica" produced by Fabian et al. (2000) by baking silica at 1220 K for 5 hours and found to be mostly Cristobalite with some indications of Tridymite. We conclude that these high temperature forms of silica have been produced in these protoplanetary disks. Perhaps even more significant than the high formation temperature is the implied cooling history of these grains. The high temperature silica polymorph must be cooled rapidly enough to "quench" the metastable structure, otherwise it would revert to the lower temperature alpha and beta quartz polymorphs. This argues for localized, transient processing in regions where the equilibrium, steady state temperatures were well below 845 K. It is interesting that the silica grain "Ada" found in the dust from the comet Wild 2 returned by the Stardust mission was Tridymite (Zolensky et al. 2006), a high temperature polymorph.

Invited Review
Disk Composition from Spectra

Jeroen Bouwman
MPIA Heidelberg

In this review I will discuss IR spectroscopic observations with Spitzer of Herbig Ae (HAE) and T Tauri (TT) systems. These latter type of systems represent the final stage of pre-main-sequence evolution oflow and intermediate-mass stars ($\sim$0.1 to 2 solar masses). The disks in HAE and TT systems most likely representthe environment in and from which the formation of planets occur. Infrared Spectroscopy provides an unparalleled tool to study the composition, i.e. the mineralogy of the dust in protoplanetary disks and the processes that play a role in its evolution. These IR observations have revealed an incredible richness of solid state emission features characteristic for dust species such as amorphous silicates, crystalline silicates, iron oxide and sulfides, ices and Polycyclic Aromatic Hydrocarbon molecules. These emission features show systematic variations which can be correlated with the evolutionary processes of the circumstellar disk. To correctly interpret the rich IR spectroscopic data, comparisons to experimental and theoretical studies are required. In this review, therefore, I will extensively discuss the interplay between observations and experiments/theory.

Coagulation and Crystallization of Silicates in Protoplanetary Disks: a c2d Spitzer/IRS Survey

Johan Olofsson
LAOG, France

Authors: Olofsson, J., Augereau, J.-C., van Dishoeck, E. F., Merín, B., Lahuis, F., Dullemond, C. P., Banhidi, Z., Bast, J., Blake, G., Boogert, A., Bottinelli, S., Brown, J., Cieza, L., Dunham, M., Evans, N., Fraser, H., Geers, V., Hogerheijde, M., Joergensen, J., van Kempen, T., Knez, C., Lommen, D., Monin, J.-L., Oberg, K., Pontoppidan, K. As part of the Cores to Disks (c2d) Legacy Program, we obtained more than a hundred of Spitzer/IRS spectra of T Tauri stars, in the spectral range 5-35 m where many silicate amorphous and crystalline solid-state features are present. Most of our objects show silicate emission features which allows both a classical study of grain coagulation and an unprecedented statistical analysis of dust crystallization in the planet forming regions in disks around young solar analogs. Analysis of the 10 micron feature indicates that grain growth has occured. Interestingly, the quasi-systematic presence of micron-sized grains in upper disks layers, from where they should have settled out on short time-scales, means that vertical mixing is active. Crystalline silicates appear to be very frequent in disks around TTauri disks and in regions much colder than their presumed formation regions, suggesting efficient outward radial transport mechanisms in disks. Their energy and the frequencies at which they are seen at wavelengths larger than 20 microns are found to be largely uncorrelated to the amorphous 10 micron feature observational properties. This provides support to our proposed compositional fitting approach to the full IRS spectral range to derive the mass fractions of crystalline and large grains in regions of different temperature in the disk. Overall, our study shows that vertical and radial transport seem to be generic dynamical processes in disks, that challenge theoretical disk evolution and planet formation models.

Imaging of Molecular Gas in Protoplanetary Disks on 1 AU Scales Using Spectro-astrometry

Klaus Pontoppidan

Caltech

Spectro-astrometry is a technique that allows milli-arcsec spatial information to be extracted from emission lines in long-slit high resolution spectra. I will present results from a spectro-astrometric survey of the CO fundamental at 4.7 micron in low-mass protoplanetary disks, obtained using CRIRES - an AO-fed R=100,000 spectrometer on the European Very Large Telescope. The spectro-astrometry allows the measurement of geometric parameters of the molecular emission from the inner disks, such as position, inclination and spatial extent. These constraints are complementary to those obtained using current infrared interferometry. The survey reveals molecular gas in Keplerian motion, as well as gas with strong departures from Keplerian motion, suggestive of significant radial motions. The survey also includes a number of transitional protoplanetary disks and demonstrates that molecular gas is present even when small dust grains have been cleared from the inner disk. I will discuss possible interpretations of this. Finally, I will show that these observations demonstrate the feasibility of direct imaging of IR molecular line emission using the future generation of extremely large telescopes, provided that these are equipped with 3-12 micron R$\sim$50-100,000 spectrometers.

Invited Review
Spatially Resolved YSO Disk Studies - Present and Future

David Wilner
Harvard-Smithsonian CfA

The Spitzer Space Telescope has remarkable sensitivity and is producing a wealth of new infrared observations of the disks around young stars, though the angular resolution is generally insufficient to spatially resolve them. Modeling unresolved panchromatic data continues to make significant advances, but as disk models become increasingly realistic and complex, spatially resolved observations are necessary to break degeneracies and to test basic model constructs. Using selected examples, I will illustrate the role of resolved observations in present disk studies. I will focus on the millimeter regime, where dust opacity is low and resolution approaches the size scale of Jupiter's orbit(or better) in some cases. Of particular interest is the determination of disk surface density distributions, which reflect the physics of accretion, inform theories of planet formation, and potentially provide indirect evidence for the presence of protoplanets. I will also discuss some of the important issues to be addressed by spatially resolved data from the improved capabilities of next generation facilities.

CARMA Observations of Proto-planetary Disks: Initial Conditions and Evolution

Andrea Isella
Caltech

Using the Combined Array for Research in Millimeter-wave Astronomy (CARMA) we have recently constrained the radial dust density distribution in 11 circumstellar proto-planetary disks in Taurus and Ophiucus star forming regions. We observe clear correlations between the disk properties (i.e., the disk radius and the shape of the surface density) and the stellar age. In the talk I will discuss these correlations in the framework of viscous disk models which enable us to constrain the initial disk structure. Finally I will discuss the effects of the disk evolution on the dust radial distribution deriving a possible time scale for the planetary formation in the observed circumstellar disks.

Protoplanetary Disk Structure with the SMA

Sean Andrews
Harvard-Smithsonian CfA

We present some preliminary results from a high spatial resolution (0.25$''$) Submillimeter Array survey of protoplanetary disks in Ophiuchus and TW Hydrae. Because of their sensitivity to the amount and structure of disk solids, resolved submillimeter continuum data provide unique access to the physical conditions in disks, including in particular the spatial distribution of mass on scales relevant to the planet formation process (30 AU and 12 AU for Ophiuchus and TWA sources, respectively). A simple 2D structure prescription and radiative transfer calculations are used to simultaneously reproduce the submillimeter visibilities and broadband spectral energy distribution for each of the disks in our sample. In general, we find that the radial variation of surface densities is well described by $p \approx 1$ (where $\Sigma \propto R^{-p}$), with significantly improved precision compared to previous lower-resolution studies. The implications of these structure measurements will be discussed in the contexts of the viscous evolution and planet-forming potential of disk material.

Day 2 Topical Posters

California Ballroom, Sunday through Wednesday

Poster #29: c2d-IRS Spectroscopy of Low-mass Embedded Young Stars: – Gas-phase Emission –

Fred Lahuis
SRON / Leiden Observatory

We present Spitzer-IRS observations of H_2, H_2O and various atoms including [Ne II], observed toward embedded low-mass (proto)stars in nearby star-forming regions. The sources are selected from the Spitzer "Cores to Disks" (c2d) legacy program and consist of truly embedded protostars, disk sources embedded in their remnant envelope and (self-)extincted disk sources (edge-on disks and disks extincted by foreground absorption). The environment of (embedded) protostars is complex both in its physical structure (envelopes, outflows, jets, protostellar disks) and the physical processes (accretion, irradiation by UV and/or X-rays, slow and fast outflow shocks) which take place. The mid-IR spectral range hosts a suite of diagnostic lines. By comparing the observed line emission with PDR and shock models our aim is to learn which of these physical processes dominates. Key in such an analysis is to spatially resolve emission in the Spitzer-IRS spectra. An optimal extraction method, developed by the c2d team, is used to separate both spatially unresolved (compact, up to a few hundred AU) and spatially resolved (extended, thousand AU or more) emission in IRS pointed observations. This will allow to distinguish between extended envelope emission and compact source emission associated with outflow shocks and/or the circumstellar disk.

Poster #30: Protoplanetary Disk Evolution in Serpens

Isa Oliveira
Sterrewacht Leiden

Based on the "Cores to Disks" (c2d) Spitzer Legacy maps, a rich population of young stellar objects (YSO) was uncovered in a region of $\sim$0.5 sq. degrees in the Serpens Molecular Cloud. This sample contains 150 bright YSOs with infrared excess, in a broad range of temperatures and luminosities, making Serpens an unique target region for obtaining a complete, well-defined sample of multi-wavelength observations of young stars in a possible evolutionary sequence. Follow-up complimentary observations in the optical and mid-infrared (Spitzer/IRS GO3) allow us to characterize the central stars, as well as the surrounding disks. The shape and slope of the mid-infrared excess provide information on the flaring geometry of the disks. The spectral features give constraints on grain growth and mineralogy, which in turn probes heating and radial mixing. The presence of PAH features traces UV radiation, whereas Halpha is a diagnostic of accretion. Assuming that the stars within a small region are nearly coeval, this provides direct constraints on the importance of environment and initial conditions on disk evolution. We are studying this rich population in order to connect the evolution of the disks with the evolution of their harboring stars, attempting to establish the mechanisms that determine the evolutionary sequence of protoplanetary disks.

Poster #31: Chemistry in the Inner Regions of Protoplanetary Disks

Monika Kress
San Jose State University

Interstellar material is highly processed when subjected to the physical conditions that prevail in the inner regions of protoplanetary disks, the potential birthplace of habitable planets. Polycyclic aromatic hydrocarbons (PAHs) are abundant in the interstellar medium, and they have also been observed in the disks around young stars, with evidence for destruction as well as some modification in the latter. Recently, compounds such as C2H2, HCN and CO2 have been observed in high abundances within the central 3 AU in some disks as well. Using chemical models for sooting flames, we have investigated the thermally-driven reactions involving PAHs to understand what becomes of these compounds as they are incorporated into the region where habitable planets may eventually form. We find that PAHs are destroyed over disk timescales at temperatures 900 K and higher. In the process, high abundances of C2H2 persist due to the kinetic inhibition of reactions that drive the carbon into CO and CH4. We also find that relatively high abundances of CH4 and CO2 are to be expected at chemical equilibrium at typical disk temperatures, pressures and C/O ratios. We suggest that PAH destruction in inner warm zones of protoplanetary disks is important and is the origin of abundant C2H2, CH4 and CO2.

Poster #32: Dust Particle Growth in Evolving Protoplanetary Disks

Tilman Birnstiel
Max-Planck-Institut fr Astronomie (MPIA)

State of the art protoplanetary disks models which trace the evolution of gas and the growth of dust usually neglect crucial mechanisms, i.e. the continuous infall of gas and dust which is a permanent source of small dust grains, the viscous evolution of the gas and the dust disk, or the evaporation and re-condensation of solid material at the inner edge of the disk. We present a model of gas and dust evolution all the way from embedded Class 0 towards Class II objects covering a variety of new effects and the first new results of such.

Poster #33: VLA cm-wave Observations of Disks around Intermediate Mass Stars

Leonardo Testi
ESO

We present cm-wave observations of disks around intermediate mass stars. The observations are used to constrain the properties of dust in the midplane of the disks. The derived dust properties are compared with the properties of the dust in the disk atmosphere as derived from infrared observations and with the parameters of the central star.

Poster #34: An arc of gas and dust around the wTTs DoAr21: New light on 'transitional disks'

Michiel Hogerheijde
Leiden Observatory

Adaptive-optics assisted integral-field observations of the weak-line T Tauri star DoAr21 reveals an arc of fluorescent H2 1-0 S(1) line emission at 2.12 micron. The line emission extends over an angle of nearly 180 degrees and radii between 70 and 200 AU, and is azimuthally asymmetric. An image of optically thin thermal dust emission at 18 microns shows a similar emission arc, consistent with the 'transitional' character of DoAr21's SED. We speculate that the arc of gas and dust represents either the interaction of the star with material in a cloud through which it is passing, or a global ring instability during the final stages of disk clearing. These observations show the power of high spatial resolution observations of disks with an (apparent or real) 'transitional' character.

Poster #35: Different Organic Chemistry in Disks around Sun-like and Cool Stars

Ilaria Pascucci
The Johns Hopkins University

It is generally assumed that the organic compounds of the protosolar nebula are representative to all protoplanetary disks implying that planets around different stars will have the same bulk composition. In a large dedicated effort with the Spitzer Space Telescope I will show that the organic compounds in the planet-forming region of cool stars differ from those around sun-like stars. Because over 80% of stars in the galactic disk are cooler than the Sun, our study suggests that the circumstellar organic inventory of the Solar System may be not typical.

Poster #36: Recent Results on the Circumbinary Transition Disk in KH 15D

William Herbst
Wesleyan University

Continued photometric monitoring of the binary weak T Tauri system KH 15D has allowed us to refine our model and understanding of this precessing transition disk and its central stars. By the end of the last observing season (i.e. April, 2008), neither binary component was fully visible at any time. The edge of the obscuring disk is sharp on the length scale of a fraction of a stellar radius and its location is predictable from cycle to cycle to about 1 stellar (1.3 solar) radius. There is no evidence in the optical data for small (0.1 micron) grains in the disk and various arguments suggest that the solids are now typically of sand (0.5-2 mm) size or larger. We suggest that what is unique about the KH 15D system is its geometry and orientation and that what it reveals about the physical nature of a WTTS (transition) disk may have widespread applicability.

Poster #37: Mid-infrared Modeling of CoKu Tau/4 Due to Circumbinary Disk Emission

Erick Nagel
Centro de Radiostronomia y Astrofisica

Spectra of stellar objects with high resolution obtained with Spitzer are an important source of information required for detailed modeling. A few years ago, CoKu Tau/4 mid-infrared spectra was interpreted due to the emission of the inner boundary wall of a disk. An evacuated region around the star is required because the flux at small wavelengths is completely determinate by the star flux. A former interpretation for the dust gap is either that small grains are coagulated in larger grains, or photo-evaporation due to radiation of the star or even, dynamical clearing by a planet. However, a few months ago, CoKu Tau/4 was resolved as two stars, which rejects the previous interpretations and states that the gap is produced by dynamical interactions between a disk and the binary system. Thus, our goal in this work is to model the Spitzer mid-infrared spectra of CoKu Tau/4 using the emission of the inner circumbinary disk wall, but now illuminated by both stars. The comparison between the observation and the model, allows to restrict the orbital parameters of the binary system and to say something of the dust composition of such wall.

Poster #38: The Outburst of EX Lup - Observational Constraints on Crystallization and Vertical Mixing in the Disk

Attila Juhasz
Max-Planck-Institute for Astronomy

EX Lup, the prototype of the EXor class of young eruptive stars, reported to show the most recent outburst in January 2008. The amplitude of the brightening at visual wavelengths was about 4 mag, the highest since the 1950s. We used this opportunity to observe EX Lup at all possible wavelengths from optical to sub-millimeter in order to study the mechanism of the outburst and look for the formation of silicate crystals during the outburst. We modelled the SED and the mid-infrared visibilities of EX Lup in the outburst and then during the fading using a 2D radiative transfer code and a vertical mixing code, with specialattention to the 10 um silicate feature. We discuss the observational results of Spitzer IRS and VLTI/MIDI measurements and their implications to the formation of crystalline silicates and the vertical mixing in the disk.

Poster #39: Accretion of Gas onto Young Circumstellar Disks: Implications for Disks and Planets

Henry Throop
SWRI

Young stars orbiting within young star clusters pass through the cluster's dense molecular gas and can experience Bondi-Hoyle accretion from reservoirs outside their individual protostellar cloud cores. Accretion can occur for several million years after the stars form, but before the cluster disperses. This accretion is predominantly onto the disk and not the star. We present simulations of accretion by stars orbiting in a variety of young clusters, from N=30 to N=3000 stars. The simulations include the gravitational potential of the molecular gas which smoothly disperses over time. We find that the disks surrounding solar-mass stars accrete roughly 10^{-8} M_{sol}/yr (1 MMSN per Myr). The accretion rate scales as M^2 for stars of mass M. The accretion rate is a few times lower for N=3000 cluster, due to its higher stellar velocities and higher temperature. The Bondi-Hoyle accretion rates onto the disks are comparable to the accretion rates observed directly onto young stars (e.g., Muzerolle et al 2005): these two accretion rates follow the same M^2 behavior and may be related. The accreted disk mass is large enough that it may have a substantial and unappreciated effect on disk structure and the formation of planetary systems. We discuss a variety of implications of this process, including its effect on metallicity differences between cluster stars, compositional differences between a star and its disk, the formation of terrestrial and gas-giant planets, and isotopic anomalies observed in our Solar System.

Poster #40: Growth of Settling Dust Particles in Turbulent Disks

Taku Takeuchi
Kobe University

Dust growth and settling in turbulent disks are studied by solving a coagulation equation. We consider dust particles that settle toward the disk midplane, and solved a coagulation equation. We assumed that the disk has weak turbulence (alpha $\sim 10^{-5}$), and that dust collisions always result in coagulation without any fragmentation. We investigated when the midplane dust layer forms. The formation time of the dust layer depends on what size we pay attention. The first generation of particles grows during their sedimentation. Even after the first generation has settled on the midplane, there remains some dust at high altitudes, and they continue to fall onto the dust layer. Suppose we focus on a specific size of the dust. The formation of the dust layer of that specific size completes when the dust materials above the layer deplete. For the dust particles to grow larger than a certain size during sedimentation, it is required that an enough amount of the dust remains above the layer. This required amount of the dust is larger for larger particles to grow. After the dust above the layer depletes, the structure of the layer settles to the steady one that determined by the balance between sedimentation and turbulent diffusion, that can be obtained analytically. For particles larger than 1 cm, the dust layer always has the steady structure, even when the first generation appears at the midplane. We compared the dust growth timescale to that of dust radial drift. For the dust to grow larger than the critical size at that the particles drift fastest, the turbulence must be weak (alpha $< 10^{-7}$) or the initial dust/gas ratio is large ($>$ 0.1).

Poster #41: Deuterium Fractionation in Protoplanetary Disks

Chunhua Qi
Harvard-Smithsonian CfA

Deuterated molecule chemistry is sensitive to the temperature history of interstellar and circumstellar gas, and observations of deuterated species can constrain the origin of primitive solar system bodies such as comets and other icy planetesimals. We present Submillimeter Array observations of the HCO+, DCO+, HCN and DCN J=3-2 lines in the disks around the K8V star TW Hya andthe A1V star HD 163296 at arcsecond scales. We constrain the radial and vertical distributions of various species using a model where the molecular emission from an irradiated accretiondisk is sampled with a 2D Monte Carlo radiative transfer code. We find enhanced molecular D/H ratios in both disks, and we attribute these enhancements to different processes. In the cold disk of TW Hya, the DCO+/HCO+ ratio increases with increasing radius due to low temperatures far from the star, as expected from low-temperature gas-phase deuterium fractionation processes. In the warm disk of HD 163296, these processes should be prohibited. Instead, grain sublimation and chemistry involved with deuterated isotopologues of formaldehyde and methanol likely contribute to the observed high deuteration.

Poster #42: Spitzer + SMA Observations of an Edge-on Disk in Corona Australis

Dawn Peterson
Harvard-Smithsonian CfA

We present high resolution Spitzer and SMA observations of a Class I young stellar object (YSO) in the nearby (150 pc) Corona Australis (CrA) star-forming region. Combined infrared and submillimeter observations provide important complementary information about the distribution of the star-forming material, from the inner envelopes to disks around YSOs. Archival single-dish 850 micron SCUBA maps provide a good estimate of the disk + envelope mass. The SMA, with its excellent angular resolution, can detect the cold outer regions of the disk, and Spitzer is sensitive to the warm inner disk and the star. Taken together, these data allow us to disentangle star from disk, and disk from envelope, the first step toward establishing the evolutionary timescales for the early stages of star formation (Lommen et al. 2008; Jorgensen et al. 2007). We constructed spectral energy distributionsfor YSO candidates in CrA from known J,H,K-band fluxes (2MASS) and Spitzer photometry (3.6-24 micron). Several candidates were observed with the SMA, and one source, IRAS 32 (SMM 8), which displays an extended near-infrared nebula in the infrared, shows a clear CO outflow (and high velocity jet). To first order, the relative contributions of the envelope and disk to the total mass of the protostar can be determined by direct comparison between the single-dish and interferometric continuum data. This explores the relationship between the mid-infrared classification and the evolutionary stage of the protostar in terms of disk and envelope structure – and can be directly compared to the existing data for the well-studied star forming regions in Ophiuchus and Taurus. For more sophisticated density and temperature structures of the protostellar envelope and disk, we use available 2D dust radiative transfer model tools to reproduce the full SEDs from near-infrared through millimeter wavelengths.

Poster #43: Long-wavelength Excesses of FU Orionis Objects: Flared Outer Disks or Infalling envelopes?

Zhaohuan Zhu
University of Michigan

The mid- to far-infrared emission of the outbursting FU Orionis objects has been attributed either to a flared outer disk or to an infalling envelope. We revisit this issue using detailed radiative transfer calculations to model the recent, high signal-to-noise data from the IRS instrument on the Spitzer Space Telescope. In the case of FU Ori, we find that a physically-plausible flared disk irradiated by the central accretion disk matches the observations. Building on our previous work, our accretion disk model with outer disk irradiation by the inner disk reproduces the spectral energy distribution between ~4000 angstroms to ~40 microns. Our model is consistent with near-infrared interferometry but there are some inconsistencies with mid-infared interferometric results. Including the outer disk allows us to refine our estimate of the outer radius of the outbursting, high mass accretion rate disk in FU Ori as $\sim$ 0.5 AU, which is a crucial parameter in assessing theories of the FU Orionis phenomenon. We are able to place an upper limit on the mass infall rate of any remnant envelope infall rate to $\sim 7 \times 10^{-7}$ Msun/yr assuming a centrifugal radius of 200 AU. The FUor BBW 76 is also well modelled by a 0.6 AU inner disk and a flared outer disk. However, V1515 Cyg requires an envelope with an outflow cavity to adequately reproduce the IRS spectrum. In contrast with the suggestion by Green et al., we do not require a flattened envelope to match the observations; the inferred cavity shape is qualitatively consistent with typical protostellar envelopes. This variety of dusty structures suggests that the FU Orionis phase can be present at either early or late stages of protostellar evolution.

Poster #44: Near-to-far Infrared Variability of EX Lup-type Stars: Clues to Disk Structure and Accretion

Agnes Kospal
Leiden Observatory

EX Lupi-type stars (EXors) are low-mass pre-main sequence stars exhibiting large, repetitive optical outbursts, thought to be powered by enhanced accretion from the circumstellar disk to the star. The brightness evolution of EXors in the near-to-far infrared regime has never been studied, although this is the wavelength range where the emission is dominated by the circumstellar material. By analyzing how changing accretion and illumination affect different parts of the disk, infrared flux variations help us to gather information on disk structure and energetics and to clarify the role of the circumstellar material in the eruption. We investigate the brightness evolution of four well-kown EXors: the prototype EX Lup, as well as DR Tau, VY Tau and UZ Tau E. Using archival Spitzer data to obtain their spectral energy distributions (SEDs), we compare these SEDs with ones derived from IRAS, ISO, 2MASS, and ground-based measurements taken in the last 25 years. We report, for the first time, clear flux changes at infrared wavelengths for several targets. The wavelength dependence of the flux changes varies considerably from star to star. By modelling the wavelength dependence of the flux changes with a radiative transfer code, we test whether variable accretion can account for the observations or geometric changes should also be invoked.

Poster #45: Understanding the Diversity of Properties of Protoplanetary Disks in Taurus

Nathan Crockett
University of Michigan

In a comprehensive study of all the stars surrounded by disks in the Taurus molecular cloud, Furlan et al. (2006) classified Spitzer IRS observations according the slope of the spectral energy distribution and the strength of the silicate emission feature. These observations characterize the dust settling and thus the depletion of dust in the upper layers of circumstellar disks. We combine these observations with submillimeter continuum observations from Andrews and Williams (2005), which probe the midplane in the outer regions of dust disks. Considering these data sets simultaneously, in effect, links the upper layers to the disk midplane. In particular, we are able to link the amount of dust settling in the upper layers to grain growth in the midplane, both quantified using our irradiated accretion disk models. Preliminary results indicate that disks with moderate grain growth in the midplane, signified by relatively steep submillimeter slopes, show a large range of dust depletion in the upper layers (from approximately 10-0.1% of the standard dust to gas mass ratio). In contrast, those disks with the flattest slopes in the millimeter are found to have the highest degrees of dust settling in the upper layers, suggesting that those disks are clearly in a much more advanced stage of evolution.

Poster #46: The Relation of H2 Gas and Dust in Disks of Accreting Stars

Laura Ingleby
University of Michigan

Although detailed studies of the gas and dust in the inner disks around low mass pre- main sequence objects exist, the relationship between the gas and dust in those disks is still unknown. To study this relationship we examine the properties of gas in the Far UV (FUV), where recent observations have revealed the presence of H2 lines excited by Ly alpha fluorescence, which are produced in the inner disk gas. We compare these properties to those of the dust, by examining the slope of the spectral energy distribution in the Spitzer/IRS range, which is a diagnostic of dust settling. With increased settling, the optical depth to high energy photons in the disk decreases and the gas is heated, so we expect H2 emission to increase with settling. We present and analyze Advanced Camera for Surveys (ACS) FUV data of 15 classical T Tauri stars (CTSSs) and Space Telescope Imaging Spectrograph (STIS) data of 4 additional CTTSs in the Taurus molecular cloud. In addition, we have Spitzer IRS spectra and IRAC photometry of each of these sources, resulting in FUV through mid-IR coverage of 19 CTTSs; a range of wavelengths important for studying both the gas and dust in the disk. We analyze the properties of the gas and dust for these sources and discuss how these properties relate to each other.

Poster #47: Panchromatic Analysis of a Circumstellar Disk: The HV Tau C Edge-on Disk

Gaspard Duchêne
UC Berkeley

Circumstellar disks can be studied through a variety of observations that includes their broadband SED, mid-infrared spectroscopy, millimeter thermal emission maps, and scattered light images. These approaches all probe different dust populations and separate regions of the disk, and it is impossible to uniquely determine all disk properties using a single observation. Instead, it is critical to combine all datasets in a consistent analysis to obtain stringent constraints on the structure and content of protoplanetary disks. Optically thick edge-on disks offer a great opportunity to easily obtain high resolution images but they also represent a major challenge in the mid-infrared regime, where they are extremely faint. The exquisitely sensitive Spitzer Space Telescope now provides a dense and continuous coverage of the SED of edge-on disks throughout the critical dip of their characteristic "double hump" SED, a key factor in constraining grain growth in disks. In this contribution, I will discuss the particular case of the nearly edge-on disk surrounding HV Tau C, a low-mass T Tauri star for which the available dataset is among the most complete to date, with special emphasis on data from all three Spitzer instruments. Using a single model, we simultaneously fit for the disk's optical-through-millimeter SED, scattered light images over almost a decade in wavelengths and resolved millimeter emission maps. The breadth of the considered dataset allows us to both tightly constraints some of the key parameters of the models and highlight the danger in extrapolating disk properties from a single type of observations. Applying this multi-technique, panchromatic approach to a large set of circumstellar disks will ultimately allow us to test specific predictions regarding disk evolution, such as the typical timescale for dust settling and grain growth, for instance.

Poster #48: Protostellar Disk Eruptions

Bringfried Stecklum
TLS Tautenburg

There is mounting evidence that circumstellar disks of YSOs become unstable every now and then, causing outbursts known as FU Ori phenomenon. Such an explosive event will presumably alter the disk and its envelope considerably. Signs of past outburst activity were identified for a few objects. Moreover, indications for an intermittent accretion behavior were found. The eruptions of protostellar disks might have serious implications for planet formation.

Poster #49: Multi-technique Modeling of Circumstellar Disks.

Christophe Pinte
University of Exeter

The on-going revolution due to high angular resolution observations and increasing wavelength coverage promises to unlock tightly-kept secrets of circumstellar disks. Thanks to these advances, many issues have already been addressed : putting constraints on large scale geometry of disks, finding evidences of grain growth and annealing, of dust settling, exploring dust properties evolution as a function of radius. Most of these results are based on models that emphasis on fitting either SEDs or scattered light images or, more recently, infrared spectroscopy or interferometric visibilities. In this contribution, we will present a more global approach which aims at interpreting consistently the increasing amount of observational data in the framework of a single model, in order to get a more global picture and to better characterize both the dust population and the disk properties. Results of such a modeling applied to a few disks (IRAS 04158, IM Lup) for which large observational data-sets are available (scattered light images, polarization maps, IR spectroscopy, X-ray spectrum) will be presented. Combining all these observations allows to draw strong constraints on model parameters and to establish new evidences of dust evolution and spatial differentiation like dust settling.

Poster #50: Observational Evidence for Grain Growth in CS Discs

Gwendolyn Meeus
AIP

Observations of dust emission in young, circumstellar (CS) discs have shown that the dust in those discs is much larger than that found in the interstellar medium, where the disc material originates from. Theoretical models of dust processing predict that the dust located in the hot surface of flaring discs will grow and settle into the disc mid-plane. It is in the denser mid-plane regions of the discs that planets are expected to form, in a process that starts with grain growth, continues with the formation of meter-sized objects and eventually the building of planetesimals. This work concentrates on the initial steps of planet formation, by discussing observational evidence of grain growth in discs of young (age $<$ 10 Millionyear) objects. The discs are located around stars with a wide range in mass, from the Herbig Ae/Be stars (a few Solar Masses), over the T Tauri stars(Solar-Mass) down to the Brown Dwarfs (Masses below 0.08 Msun). In this poster, I will discuss the impact of stellar parameters, such as age, mass, luminosity and the presence of close companions on dust grain evolution. I will do so by a comparison of dust properties - as witnessed by the observed dust characteristics - of objects in a single star forming region (influence of mass, luminosity, companions) but also by comparing dust properties of objects located in different regions (influence of age and environment).

Poster #51: Do X-Rays modify the Crystalline Structure of Dust in Circumstellar Disks?

Adrian Glauser
ETH Zurich

High-energy irradiation of the circumstellar material might have impact on the structure and the composition of the protoplanetary disk and hence the process of star and planet formation. We present a study on the possible influence of the stellar X-ray emission on the crystalline structure of the circumstellar dust. We measure the dust crystallinity for 42 class II T Tauri stars in the Taurus star-forming region with adecompositional fit of the 10 micron Si feature, measured with the Spitzer IRS instrument. We then correlate X-ray parameters, i.e. the X-ray luminosity and the X-ray hardness, against the crystalline mass fraction of the dust and find a significant anti-correlation for objects within an age range of 1.2 to 3 Myr. We conclude that X-rays destruct the crystalline structure of dust grains, located in the protoplanetary disk.

Poster #52: Sources of CTTS Excess Emission at One Micron

Will Fischer
University of Toledo

High-resolution Keck/NIRSPEC spectra of CTTS at one micron indicate that the continuum excess (veiling) in this wavelength regime is greater than expected from the summed contributions of the 6000-10000 K accretion-heated photosphere, which explains the optical excess, and 1400 K dust at the inner edge of the accretion disk, which explains the K-band excess (Edwards et al. 2006, ApJ). To investigate this finding in greater detail, we used SpeX on the IRTF to obtain medium-resolution (R=2000) spectra of CTTS spanning a range of accretion rates, with wavelength coverage from 0.8 to 2.4 microns. I present derived spectra of the excess emission in these objects and assess the likelihood of additional contributors to the SEDs at wavelengths intermediate to the regions where the excess is currently best understood.

Poster #53: The Origin of Unexpected Single Peaked CO Lines in Inner Regions of Protoplanetary Disks

Jeanette Bast
Leiden Observatory

CO v=1-0 emission and absorption at 4.7 micron has been observed with the new high resolution (R = 100 000, 3 km/s resolution) AO assisted (0.2″ slit) spectrometer CRIRES at the VLT for a sample of >50 T Tauri stars to study the inner hot

gaseous regions of protoplanetary disks on AU scales, in a large program led by Pontoppidan. This is a subsample of YSOs observed with the Spitzer Space Telescope 'Cores to Disks' (c2d) legacy and other programs. We focus here on analysis of the CO line profiles. In particular, the CRIRES data show two types of emission: a Keplerian velocity line profile and a single peaked line with a very broad base. The Keplerian velocity line profiles can be readily explained by rotation of an inclined disk but the single peaked CO line profiles are not consistent with this model. Searches for correlations with other parameters to distinguish these two types of sources, in particular accretion rates, will be presented together with other characteristics of the sources and possible explanations for the peaky profiles.

Poster #54: Modeling Mid-Infrared Variability in Circumstellar Disks

Kevin Flaherty
University of AZ, Steward Observatory

The Spitzer Space Telescope has opened up the possibility of obtaining time series mid-infrared observations of T-Tauri stars. A dedicated monitoring program of the young cluster IC 348 using Spitzer has found a number of stars, such as the G6 classical T-Tauri star LRLL 31, that exhibit unique and unexpected behavior. Based on IRS spectra of LRLL 31 separated by as little as a week we find that the short and long wavelength flux are anti-correlated with changes of the flux up to 30%. We present a series of simple models of this unusual variability. We consider a flat disk that is not confined to the midplane, either due to a warp at the outer edge, a warp at the inner edge or a spiral wave originating from the inner edge of the disk. These models show that the shadowing caused by a change in the height of the warp/spiral wave near the inner disk rim can reproduce the anti-correlation as well as the strength of the variability, while a precessing warp/spiral wave is unable to reproduce the observations.

Poster #55: Dust Settling and Instability in Stratified Protostellar Disks

David Tilley
University of Notre Dame

The early stages of planet formation occur in a disk that contains a mixture of dust grains of various sizes with the gas. The mutual interactions between dust and gas can alter the rate at which grains can grow into pebble and boulder-sized objects through the formation clumps in which the density of dust is greatly enhanced. To understand how this clumping develops in a stratified protostellar disk, we perform a suite of 3D shearing box simulations that model parcels of a minimum-mass solar nebula at radii of 0.3-100 AU. We examine the structure of several initially well-mixed layers of dust of different sizes as they simultaneously interact with the gaseous disk, which is turbulently driven via the magnetorotational instability (MRI). We find that large dust grains settle into a thin layer where they are subject to a streaming instability that leads to large enhancements in dust density, while smaller dust grains can remain well-mixed with the gas. We characterize the vertical distribution of the dust of different sizes at different radial positions in the disk. We contrast these results for a minimum-mass solar nebula model to one in which the gas has been depleted by a factor of twenty, while the dust density has remained unchanged – as might be found in a more evolved disk. In these latter models, feedback from the dust on the gas has a stronger effect on their mutual evolution.

Poster #56: Millimeter-Wavelength Signatures of Disk Accretion

A. Meredith Hughes
Harvard-Smithsonian CfA

We present recent results from the Submillimeter Array that use resolved observations of four nearby disk systems (HD 163296, TW Hydrae, GM Aurigae, and MWC 480) to study signatures of disk accretion. Using 1.3 and 0.87 mm continuum and CO J=3-2 data, we show that a simple model motivated by similarity solutions of the time evolution of accretion disks that includes a tapered exponential edge in the surface density distribution can reconcile the apparent discrepancy between gas and dust outer radii obtained by commonly-used models described by power laws in surface density and temperature. For two systems, we further investigate accretion processes with new observations designed to probe turbulent linewidths and magnetic field structure, the central aspects of alpha-disk models with MRI turbulence: observations of the CO J=3-2 line in the TW Hydrae disk at high spectral resolution (44 m/s) allow us to study disk kinematics at a new level of detail, while spatially resolved 0.87 mm polarimetric observations of the HD 163296 disk allow us to test the first realistic predictions of polarized emission from dust grains aligned by magnetic fields threading the disk.

Poster #57: Mid-IR Spectroscopy of Comets & Dusty Disks : Mineralogical and Elemental Clues to the Formation and Evolution of Solar Systems

Carey Lisse
JHU Applied Physics Laboratory

With observations made by the Spitzer Space Telescope, we are beginning to understand the details of how the composition and formation of our own Solar System compares to those of other stars in our Galaxy. This is a major question in astronomy, and recent, detailed observations by Spitzer of comets (remnants of the solar systems proto-planetary disk), proto-planetary disks around Young Stellar Objects, debris disks around moderate-age stars, and dust rich DZ white dwarfs have given us

a collection of detailed spectra containing clues about our Galactic context. In this contribution I will discuss Spitzer and related ISO mid-infrared (5 to 40 micron) spectroscopy of 6 comets and the dusty systems SST-LUP3-1, HD100546, HD163296, HD113766, HD172555, HD69830, G29-38 and GD362. Using the results from the recent Deep Impact and STARDUST space missions as ground truth, we can now constrain the relative abundances of silicates, carbonates, water ice/gas, amorphous carbon, sulfides, and polycyclic aromatic hydrocarbons (PAHs) in dusty disks, and directly relate the temperature of the circumstellar dust to its location with respect to the system primary. I will discuss the similarities and differences in the spectra, the amount, kind, and location of the dust and gas species detected, the primitive or advanced state of processing of the dust, compositional solar system analogues for the inferred source parent bodies, and the implications for our Solar System's origin and evolution.

Poster #58: Preferred Locations for Planet Formation in MRI Active Disks

Katherine Kretke
UCSC

The first challenge in the formation of both terrestrial planets and the cores of gas giants is the retention of grains in protoplanetary disks. In most regions of these disks, gas attains sub-Keplerian speeds as a consequence of a negative pressure gradient. Hydrodynamic drag leads to orbital decay and depletion of the solid material in the disk. However, at local pressure maximums solids and gas will move at the same velocity allowing solids to accumulate. If the viscous evolution of the disk is due to turbulence driven by the magneto-rotational instability (MRI) then radial changes in viscosity in an incompletely ionized disk, will create local pressure maxima as the disk approaches a quasi-steady state. Two locations where these pressure maximums should occur are (1) the outer boundary of the thermally ionized region (the inner edge of the dead zone) and (2) at sublimation fronts (such as the snow line) where the grain-to-gas ratio changes significantly over a short distance. These changes in viscosity will produce pressure maximums which alter the disk structure and may seed the formation of planets.

Poster #59: The Gas Component of the KH 15D Transition Disk

Samantha Lawler
Wesleyan University

High resolution spectra of KH 15D have been obtained at a variety of elevations of star A with respect to the occulting edge of its circumbinary disk. The optical light variations provide information on the opacity distribution, which comes from the solid component. Here we employ measurements of the NaI D lines to measure

the vertical distribution of gas density. Comparing the gas and dust distributions allows us to model the degree of settling of the dust in this transition disk.

Poster #60: Mid-Infrared Spectral Variability of Actively Accreting T Tauri Stars

Jarron Leisenring
University of Virginia

We present Spitzer IRS data from a multi-epoch mid-infrared spectroscopic survey of 11 actively accreting T Tauri stars in Taurus-Auriga to investigate temporal variations of the gas and dust features residing between 5 and 14 microns. Some objects exhibit the [Ne II] fine structure emission at 12.81 microns as well as the H I (7-6) emission line at 12.37 microns, both of which exhibit marginally detected variability in line flux. A correlation between these gas phase features would suggests a common origin for their emission and have the potential to constrain the responsible mechanisms. In addition, we detect a water vapor absorption band centered between 5.6 and 5.8 microns in the majority of our objects that varies on the timescale of months. We also report on the detection of variability in the 10 micron silicate feature in a few of our objects. The high accretion rates previously measured for the sources in our survey suggest that the variations in these gas phase features as well as those of the silicate features may be due to fluctuations in the accretion luminosity, high energy photons incident upon the disk, and possible line-of-sight effects due to mixing in and rotation of the disks.

Poster #61: Classification and Analysis of Ophiuchus YSOs from IRS Spectra

Melissa McClure
University of Michigan

We present the results of our guaranteed-time IRS survey of the Ophiuchus star forming region, which includes objects in the heavily embedded core region, L1688, and a smaller subset of objects in the other clouds and off-core regions. Analysis of young stellar objects is complicated by extinction along the line of sight and the inclination of each object. Using optical depths of the silicate and ice features, as well as the n2-31 and n5.3-31 micron spectral indices, we classify these objects by evolutionary stages. To apply extinction corrections to the Stage II and III objects, we determine empirical extinction curves for Av = 5-50 based on IRS spectra of K giants behind star forming regions. For $A_V < 8$ the curves lie close to the Mathis (1990) extinction curve, but for $A_V > 8$, they lie closer to the Weingartner & Draine (2001) Rv = 5.5 case B curve, a result which is consistent with that of Flaherty et al. (2007). After applying extinction corrections to the Stage II and III spectra, we determine spectral indices for each stage, study other indicators of disk evolution, and discuss emergent trends.

Poster #62: Radiative Transfer Simulations: Low Mass Cores, Disks, and Protostars

Stella Offner
UC Berkeley

Simulations are a formidable tool for testing and formulating theories when combined with careful observational comparisons. Using the Orion adaptive mesh refinement code, I simulate low mass star formation in a turbulent molecular cloud. The 3D hydrodynamic simulations include both self-gravity and gray radiative transfer. I compare the distribution of stellar masses, accretion rates, and disk properties in the cases with and without radiation feedback. I find that the influence of radiative heating is mainly limited to a few hundred AU around the source. However, an increase of only a factor of 2 in gas temperature is sufficient to suppress disk fragmentation that would otherwise result in very low mass protostars or brown dwarfs. I also calculate spectral energy distributions (SEDs) of the sources and compare with SEDs of low mass young stars observed with Spitzer.

Poster #63: A Spitzer Detection of Crystalline Silicates in a Protostar

Charles Poteet
The University of Toledo

Recent surveys with the Spitzer Space Telescope have systematically identified protostars in nearby molecular clouds. The richest sample of protostars within 500 pc of the Sun is found in the Orion A molecular cloud, where we have observed 252 protostars with the Infrared Spectrograph (IRS) on board the Spitzer Space Telescope. Here, we present the IRS spectrum of the Orion A protostar 8385127-5141. The mid-infrared spectrum reveals the discovery of crystalline substructure in the amorphous silicate absorption features. Crystalline silicates are often observed as infrared emission features around the circumstellar disk of Herbig Ae/Be stars and T-Tauri stars, but this is only the second instance of crystalline features being detected in the envelope of a protostar, and it is to our knowledge, the first instance of these absorption features being observed in a protostar with Spitzer. Using radiative transfer models, we investigate the nature of the central protostar and its envelope structure, as well as discuss the implications of crystalline silicates in the protostellar environment.

Poster #64: Evidence for a Photoevaporated Circumbinary Disk in Orion

Luca Ricci
European Southern Observatory

We report on the first circumbinary disk seen in silhouette against the bright nebular background of the Orion Nebula. Using multicolor observations taken with the ACS/WFC onboard the Hubble Space Telescope as part of the HST Treasury Program on the Orion Nebula Cluster, we show that source 124-132, a photoevaporated disk previously imaged in Halpha, harbours a double star. The angular separation between the two point-like sources is approximately 0.15", corresponding to a projected separation of about 60 AU at the distance of the Orion Nebula. The two sources have nearly identical magnitudes in both the I and z bands. Their position in the color-magnitude diagram is compatible with low mass brown dwarfs with substantial accretion luminosity. The projected radius of the silhouette disk, about 100 AU, is larger than the projected sources separation. Even if a model with two coplanar circumstellar disks may explain the observations, the nearly identical brightness and colors of the stars more likely points to the presence of common foreground material, i.e. a circumbinary disk affecting their observed fluxes in a similar way.

Poster #65: A Sub-milli-arcsecond View of the Gas-Dust transition Region in Herbig Ae Stars.

Ajay-Kumar Tannirkulam
U. Michigan

Contrary to the predictions of 'standard' models, we have detected strong near-infrared (NIR) emission from hot gas in the prototype Herbig Ae stars MWC275 and AB Aur. Using the sub-milli-arcsecond resolution of the CHARA interferometer array, we place the gas emission to be interior to and on the same spatial scale as the dust sublimation radius. In the absence of shielding of starlight by gas, we demonstrate that the dust evaporation front in these young stellar objects (YSOs) will have to contain highly refractory dust sublimating at 1850K. MWC275 and AB Aur have very similar structures in the thermal NIR, and yet their outer disks are substantially different. As opposed to MWC275, AB Aur has a substantial amount of small dust grains in the disk atmosphere even beyond 10 AU that produce significant 10-20 micron emission, indicating the presence planetesimal collisions that maintain the small grain population.

Poster #66: Signatures of Emission from Organic Molecules in Low Resolution Spitzer Spectra of T Tauri Stars

Johanna Teske
University of Arizona/Steward

We explore the extent to which Spitzer IRS spectra taken at low spectral resolution can be used to study organic molecule emission from disks surrounding low mass

young stars. Guided by Spitzer IRS spectra taken at high spectral resolution (e.g., Carr & Najita 2008) and using low resolution IRS spectra of the same sources (Furlan et al. 2006), we investigate whether it is possible to define spectral indices that can measure the strength of molecular bands such as C2H2, HCN, and CO2 and blends of H2O lines in low resolution data. If suitable spectral indices can be identified, they can be used to search for and study molecular emission in the large number of circumstellar disk spectra taken at low resolution that now reside in the Spitzer archive. Such studies would complement results for the much smaller number of circumstellar disks that have been observed at high resolution with IRS.

Poster #67: ProDiMo - Disk Models for GASPS

Peter Woitke
ATC Edinburgh

With the launch of the HERSCHEL observatory we will be able to study far IR gas emission lines from protoplanetary disks, which allows us to determine directly the gas mass and discuss the stucture and evolution of the gas phase independent of the dust. In our GASPS open time key programme, we will observe fine structure lines of CII and OI, as well as rotational lines of CO and H2O that probe the surface, the body and the midplane regions of the disks, respectively. For a qualified interpretation of these observational data, we need accurate models. In this contribution, I will present new models ("ProDiMo"), based on the work of Inga Kamp, that consistently solve the kinetic chemical equilibrium in the gas phase, the balance of non-LTE heating and cooling rates, the 2D dust continuum radiative transfer and the vertical hydrostatic disk stratification. Current results suggest that the gas is quite hot at the surface ($>$1000K at 1AU) and, thus, the disks are vertically much more extended than previously expected. These warm puffed-up surface layers are important to understand and non-LTE line transfer and to interpret the observational line data.

Poster #68: Characterising the Gravitational Instability in Cooling Accretion Discs

Peter Cossins
University of Leicester

We use 3D global numerical simulations to perform a systematic analysis of the structure induced by the onset of gravitational instabilities in cooling gaseous accretion discs. For low enough cooling rates, discs reach a quasi-steady configuration, with the instability saturating at a finite amplitude where the disc is close to marginal stability. We analyse the dependence of the saturation amplitude on the cooling rate, and we find that it scales with the inverse square root of the cooling parameter $\beta = t_{cool}/t_{dyn}$. This indicates that the heating rate induced by the instability is a fixed fraction of the energy density of the waves excited by the disc self-gravity. In particular, we find that at saturation the energy dissipated per dynamical time by shocks due to the gravitational perturbations is approximately 20 per cent of the wave energy. We perform a Fourier analysis of the disc to determine the dominant radial and azimuthal wavenumbers. While the azimuthal wavenumber is almost constant with radius, we find that the disc displays a large number of radial modes with wavelengths increasing with increasing radius. The dominant modes closely match the locally most unstable wavelength predicted by linear perturbation analysis. As a consequence, we demonstrate that the density waves excited in relatively low mass discs M_{disc} / $M_{*} \sim 0.1$ are always close to corotation, deviating from it by no more than 10%. This has profound effects on how accurately the extraction of energy and angular momentum from the mean flow can be modelled viscously. Our results provide (a) a detailed description of how the self-regulation mechanism is established for low cooling rates, (b) clarification of the conditions required for describing self-gravity induced transport with an effective viscosity, (c) an estimate of the maximum amplitude of the density perturbation before fragmentation takes place, and (d) a simple means of estimating the density perturbation in different thermal regimes.

Poster #69: Rotational Line Emission from Water in Protoplanetary Disks

Rowin Meijerink
UC Berkeley

Circumstellar disks provide the material reservoir for the growth of young stars and for planet formation. We combine a high-level radiative transfer program with a thermal-chemical model of a typical T Tauri star disk to investigate the diagnostic potential of the far-infrared lines of water for probing disk structure. We discuss the observability of pure rotational H_2O lines with the Herschel Space Observatory, specifically the residual gas where water is mainly frozen out.

Poster #70: PAH Evolution from Clouds to Disks around Low-mass YSOs

Vincent Geers
University of Toronto

We present the results of several large surveys of PAHs in star-forming regions, from embedded objects to disks around low-mass YSOs. Spitzer-IRS, VLT-ISAAC and VLT-VISIR spectroscopy is presented and combined with radiative transfer modeling to address several questions: How abundant are PAHs in low-mass young star systems? What happens to PAHs in the embedded phase of a forming star? Does the PAH emission originate from the envelope or from the disk? What do they tell us about disk structure and grain growth?

Poster #71: The First Spatially Resolved Mid-IR Spectra of Binaries with Adaptive Optics

Andrew Skemer
University of Arizona, Steward Observatory

Spitzer IRS spectroscopy has revealed a variety of silicate morphologies in young stars, indicating dust-grain evolution and other disk phenomena. However, Spitzer's limited angular resolution makes it impossible to resolve all but the widest binaries, so many IRS spectra are potentially mixtures of multiple silicate features. Large ground-based systems can spatially and spectrally resolve these structures. We describe our ongoing survey to resolve the silicate features of Taurus binaries (T Tauri, XZ Tauri, etc.) down to separations of 0.1$''$, using the 6.5 meter MMT with its unique mid-IR adaptive optics system. Our survey will allow us to determine how the silicate feature varies between binary components, which will be an important clue for determining the initial steps of grain-growth and planet formation.

Poster #72: Spatially resolved 4.7 micron CO fundamental emission in two protoplanetary disks

Gerrit van der Plas
University of Amsterdam/ Anton Pannenkoek Instituut

We present high-spectral-resolution 4.6-5.1 μm spectra of HD 100546 and HD 97048 containing fundamental CO emission taken with the CRIRES on the VLT. We resolve, spectrally and spatially, the emission of the ^{13}CO v(1-0) vibrational band and the ^{12}CO v(1-0), v(2-1), v(3-2) and v(4-3) vibrational bands in both targets, as well as the ^{12}CO v(5-4) band in HD 100546. Using these data, we constrain the emitting regions in two independent ways. First by modeling the kinematics of the spectral line profiles, and secondly using astrometry.

Poster #73: Effects of Accretion Flow on Chemical Structure and Dust Distributions in Protoplanetary Disks

Hideko Namura
Kyoto University

The Spitzer Space Telescope have observed the dust continuum emission toward many young circumstellar disks and, in addition, warm molecular lines have been observed toward some disks. Now, accretion flow toward a central star is important for planet formation in the disks, because it is one of the possible mechanisms for the dispersal of the gas, and it will be useful if we can identify observational evidence for the accretion flow in the inner disk. In this work we study the effects of the gas accretion flow on the distribution of molecules in hot inner regions as well as on the spatial and size distribution of dust particles in protoplanetary disks. First, we

have performed model calculations of the time-dependent chemical reactions along the accretion flow, which are initiated by ice mantle evaporation, and studied the dependence of the profiles of molecular abundances in the hot ($>$100K) inner disks on the accretion flow. Our results have shown that the high C2H2 abundance observed toward a T Tauri star could suggest relatively high accretion velocity in the disks. We have also compared our results with the observed abundances of other warm molecules. Second, we have calculated numerically the coagulation equation for settling and radially moving dust particles, and studied the influence of the accretion flow as well as of the infalling dust particles from the surrounding molecular clouds on the dust continuum emission from the disks. Our results have demonstrated that when the density of the surrounding cloud is high ($> 10^4 cm^{-3}$) or the viscous parameter, alpha, is high enough ($>$0.001), the observed infrared excess radiation emitted from the dust grains in the disks can be reproduced.

Day 3 Oral Presentations

Invited Review
From T Tauri Disks to Transitional Disks: Accretion and Planetesimal Formation

Eugene Chiang
UC Berkeley

What physical processes operate in transitional disks to clear and maintain their central cavities? The enormous reductions in optical depth implied by observations require consolidation of dust into larger objects—possibly planet-sized as an extreme hypothesis. We discuss recent developments in our understanding of how solids coagulate, highlighting gravitational instability at the dust-rich midplane. It is shown how the traditional objection to gravitational instability—turbulence triggered by vertical shearing instabilities—might be circumvented, by having the disk be of supersolar metallicity. Once the inner disk initially rids itself of opaque dust, there is the further problem of maintaining the central clearing against ongoing accretion from the outer disk. Planets, though they may exist in the hole and be responsible for its initial clearing, cannot easily gate the accretion flow by themselves. An alternative means by which accretion can be regulated involves the magneto-rotational instability (MRI) operating at the disk rim. Transitional disks present promising environments for the MRI because they are devoid of dust. In this scheme, gas is leached from the rim at a rate set by the depth to which stellar X-rays ionize the rim wall. Blown out by radiation pressure, dust fails to accrete with gas. We present a testable prediction of this mechanism.

Disk census in the star-forming regions of the Orion OB associations

Jesus Hernandez
University of Michigan

Combining optical/2MASS data with IRAC/MIPS photometry, we are carrying out a systematic study to identify and characterize disk populations in star-forming regions of the Orion OB associations, including the sigma Orionis cluster, the lambda Orionis cluster, a subregion of the OB1b sub-association, and the 25 Orionis stellar aggregate in Ori OB1a, which range in age from $\sim$3 to $\sim$10 Myr. Our samples are optimal for studying disk evolution; for one thing, observations and theoretical studies indicate that key process in the evolution of protoplanetary disks take place in the 3-10 Myrage range. In addition, the samples are relatively near ($<$500 pc), allowing us to probe a wide range of stellar masses, from intermediate masses down to the substellar regime. Finally, these populations most likely share a common origin from the same giant molecular cloud, minimizing evolutionary effects due to differences in initial environments. In this comparative study we address issues as the mass-dependence and age-dependence of the frequency of primordial disks. We also quantify the decrease of near infrared emission and the clearing of the inner regions of primordial disks with age, and how these interrelate to the appearance of the debris disk phenomena. We compare our observation with predictions of detailed models of primordial and debris disks, to identify the main agents guiding the evolution and the transition from primordial to debris dust.

The Role of Multiplicity in Protoplanetary Disk Evolution

Adam Kraus
Caltech

Interactions with close stellar or planetary companions can significantly influence the evolution and lifetime of protoplanetary disks. It has recently become possible to search for these companions, directly studying the role of multiplicity in protoplanetary disk evolution. I will describe an ongoing survey to directly detect these stellar and planetary companions in nearby star-forming regions. This survey uses adaptive optics and sparse aperture masking to achieve typical contrast limits of DeltaK=5-6 at the diffraction limit (5-8 MJup at 5-30 AU), while also detecting similar-flux binary companions at separations as low as 15 mas (2.5 AU). Aside from the new binary system CoKu Tau/4, our survey has found no evidence of companions (planetary or binary) among the well-known "transitional disk" systems; if the inner clearings are due to planet formation, as has been previously suggested, then this paucity places an upper limit on the mass of any resulting planet. Our survey also has uncovered many new binary systems, with a majority falling among the diskless (WTTS) population. This disparity suggests that disk evolution for close (5-30 AU) binary systems is very different than for single stars; most circumbinary disks are cleared by ages of 1-2 Myr, while most circumstellar disks are not. These diskless binary systems have biased the disk frequency downward in previous studies; if we remove our new systems from those samples, we find that the disk fraction for single stars could be higher than was previously suggested.

Invited Review
The Evolution and Dispersal of Gas Discs

Richard Alexander
Leiden Observatory

I review recent developments in the modelling of disc evolution and dispersal. I will first present the standard picture of gas disc evolution, in which the gas disc evolves subject to viscous transport of angular momentum and photoevaporation by radiation from the central star. There are, however, a number of uncertainties and problems associated with this picture, which I will discuss along with current work that seeks to address these issues. I also consider recent observations of so-called transitional discs, thought to be "caught in the act" of disc clearing, and discuss the successes and failures of different models in the transitional regime. Lastly I will discuss prospects for observations of gas disc evolution in the near future, highlighting a number of potentially interesting diagnostics.

Is Mid-Infrared [Ne II] Emission a Tracer for X-Ray Ionized and Heated Gas in Protoplanetary Disks?

Manuel Guedel
ETH Zurich

Circumstellar dust disks are the most important elements in the process of planet formation. They have been well studied through imaging and infrared spectroscopy. The gas in which the dust is immersed is much more challenging to observe; yet, gas is fundamentally important to determine temperature and density gradients in the disk, to drive a chemistry forming important molecules, and to control the dynamics of the dust itself. Glassgold et al. (2007) proposed that the forbidden mid-infrared [Ne II] transition at 12.81 microns is a tracer of warm gas requiring X-ray irradiation of the disk. As the X-rays also heat the upper layers of the gas disk to several 1000 K, [Ne II] fine-structure transitions are produced. Observations of the [Ne II] transition may detect relatively small amounts of warm gas in the inner, planet-forming disk zone (R=10-20 AU), at the same time confirming the role stellar X-rays play in driving disk dynamics, accretion, chemistry, and eventually the formation of planets. Theories of [Ne II] line production predict - for otherwise identical source and disk properties - a linear correlation between the [Ne II] and the X-ray luminosities. Undoubtedly, however, further parameters are relevant, such as, and in particular, the X-ray spectral hardness and the disk mass. Our ongoing project studies links between [Ne II] emission, stellar X-rays, and other stellar and disk parameters, both observationally and theoretically. We present results from this project and discuss them in the context of theories of [Ne II] emission in young stellar environments.

The Observation of Warm Gas in Transitional Disks around Herbig Ae/Be Stars

Sean Brittain
Clemson University

We present recent results from our ongoing survey of CO in transitional disks around Herbig Ae/Be stars. High-resolution spectroscopy of ro-vibrational CO emission provides unrivaled views of the distribution of gas in disks and neatly complements studies of the dusty content and structure of disks to emerge from Spitzer and MIR ground-based instruments. CO is well suited to probing the inner, planet-forming regions of disks because it is relatively stable and becomes self-shielding at column densities as low as 10^{14} cm^{-2}. In this talk we will present results from our modeling of UV fluoresced CO in disks around HAeBe stars and highlight what the data tell us about the heating mechanisms of molecular gas in disks. We will also discuss the implications various excitation mechanisms have on the apparent abundance of CO isotopomers such as ^{13}CO and C^{18}O. Finally, we will present constraints on the settling of dust in transitional disks as inferred from modeling the gaseous emission.

Invited Review
Gas in Inner Disks

Joan Najita
NOAO

I will review recent progress made by Spitzer and other facilities in characterizing the inner regions of gaseous disks surrounding young stars. New probes of gaseous inner disks include mid-infrared molecular transitions of water and organic molecules as well as atomic transitions such as NeII. These and other previously known diagnostics can be used to probe the radial structure of disks and their chemical evolution, and to search for evidence of planet formation in various evolutionary stages. Work to date suggests a bright future for studies of gaseous inner disks.

Disk Evolution in Taurus, Ophiuchus, and Chamaeleon I

Elise Furlan

JPL / Caltech

We present an analysis of Spitzer-IRS spectra of T Tauri stars in Taurus, Ophiuchus, and Chamaeleon I, which are three nearby star-forming regions of comparable age (1-2 Myr), but with differing environments. The IRS spectra reveal emission from dust in the inner few AU of the disks around these stars and thus probe the region where planets are thought to form. We compare the median IRS spectra of T Tauri stars in these three regions, and we use the spectral index at mid-infrared wavelengths together with the strength of the silicate emission feature to derive and compare the degree of disk evolution in the three young regions. We conclude that dust settling and radial structure formation is well under way in disks at an age of 1-2 Myr.

Invited Review

The Spitzer Census of Transition Disks

James Muzerolle

University of Arizona, Steward Observatory

Spitzer is making great strides in our understanding of disk evolution. In particular, detailed studies of transition disks, protoplanetary disks with AU-scale inner "holes", are now possible, with Spitzer's sensitivity and efficient mapping providing statistically significant samples for the first time. I will present the latest results on transition disk statistics, showing trends as a function of stellar properties such as mass, age, accretion, and environment. There are significant dependences with stellar mass and age, which suggest that multiple mechanisms may be responsible for inner disk clearing. I will review the leading possibilities, including dust grain growth, viscous evolution, photoevaporation, and dynamical clearing from a binary companion or newly formed giant planet. I will also touch upon nomenclature, particularly what "transition" really means and whether it represents a universal phase of disk evolution connecting protoplanetary and debris disks. Time permitting, I will present new observations of mid-infrared variability in some transition objects and discuss implications for following changes in disk structure, possibly as a result of dynamical interactions with stellar or planetary companions.

Debris Disks and the Formation of Terrestrial and Icy Planets

Thayne Currie

Harvard-Smithsonian CfA

I discuss new insights into the time history of terrestrial and icy planet formation provided by recent Spitzer observations of debris disks surrounding stars in h and chi Persei, Orion OB1, NGC 2547, and other 5–35 Myr-old clusters/associations. I present new statistical trends in the frequency of terrestrial and icy planet formation as a function of age and stellar properties and a possible, new evolutionary link between primordial disks and debris disks. I also consider the evolution of debris emission from icy planet formation. By relating these observed trends to predictions from theoretical models of planet formation, I describe how this evolution provides evidence for the growth of lunar to Mars-sized oligarchs from smaller planetesimals. Finally, I discuss challenges that these results pose for models of planet formation and their ability to explain observed exoplanet trends.

Day 3 Topical Posters

California Ballroom, Sunday through Wednesday

Poster #74: Thermochemical Structure and Photoevaporation of X-ray Irradiated Protoplanetary Disk Atmospheres

Barbara Ercolano
Institute of Astronomy, University of Cambridge

The evolution of protoplanetary discs and of their planetary progeny is controlled by heating and irradiation from the central star - from IR to X-rays - but in the vicinity of OB stars can also be significantly affected by the external radiation environment. Observations of protoplanetary discs have already begun to represent an important aspect of Spitzer's legacy, these and other observations are providing insight into problems such as the timescales for grain growth and gas dissipation, angular momentum transport - issues central to understanding the likelihood of forming planetary systems like our own. While the observational database continues to grow, and several studies have focused on the properties of the dust component of the disc atmospheres, studies of the gaseous component of the inner discs have only recently been attempted. So far only a rough picture of the thermochemical structure of this crucial component has been provided. I will present results from our 2D photoionisation and dust radiative transfer modeling of realistic, irradiated T-Tauri disks, highlighting their decoupled dust and gas temperature structure and ionisation structure, and discussing the contribution of X-ray photoevaporation to disk dissipation. Gas-phase diagnostics (e.g.[NeII] 12.8um) will be mapped across the disk surface, and predictions will be made for useful gas-phase diagnostics that are detectable with current instrumentation or will become so in the near future.

Poster #75: Spectroscopic Update on the "Moon Star"

Nadya Gorlova
University of Florida

To probe whether they represented huge collisions like the one that formed our Moon, we obtained VLT echelle spectra of two stars with strong IR excesses in the 40 Myr-old cluster NGC 2547 (Gorlova et al. ApJ 2007). The following parameters were examined to assess membership in the cluster: radial velocity, chromospheric activity, lithium, surface gravity, metallicity, and the spectroscopic parallax. ID9 and one comparison star appear to be old background G-K giants. ID9 could be an RV Tau system with a circumbinary disk mimicking that of classical TTau stars. On the other hand ID8 (the "Moon star") is confirmed to be a member of roughly solar-type, reinforcing the interpretation of its optically-thin disk as a result of a protoplanetary collision, similar to one that created Moon in the Solar system.

Poster #76: SPITZER and HST Observations of Photoevaporating Disks

Zoltan Balog
University of Arizona, Steward Observatory

I will discuss Spitzer and HST observations of protoplanetary disks being photoevaporated around high-mass O-type stars. 24 micron observations show that these objects have "cometary" structure, where the dust pulled away from the disk is forced away from the O star by photon pressure. Models of the 24 and 8 micron brightness profiles agree with this hypothesis. We find no Pa alpha emission in any of the systems. The resulting upper limits correspond to about 0.000002-0.000003 solar mass of mass in hydrogen in the tails suggesting that the gas is severely depleted. The IRAC data and the low resolution 5-12 micron IRS spectra provide evidence for an inner disk while high resolution long wavelength (14-30 micron) IRS spectra confirm the presence of a gas free "tail" that consists of $\sim$0.01 to $\sim$1 micron dust grains originating in the outerparts of the circumstellar disks. Overall our observations support theoretical predictions in which photoevaporation removes the gas relatively quickly from the outer region of a protoplanetary disk but leaves an inner more robust and possibly gas-rich disk component of radius 5-10 AU. With the gas gone, larger solid bodies in the outer disk can experience a high rate of collisions and produce elevated amounts of dust. This dust is being stripped from the system by the photon pressure of the O star to form a gas-free dusty tail.

Poster #77: Photoevaporation of Viscously Evolving Circumstellar Disks by FUV, EUV and X-ray Radiation from the Central Star

Uma Gorti
SETI Institute

We present theoretical models of the photoevaporation of disks by high energy radiation (FUV, UV and X-rays) from the central star, and include the effects of viscous evolution. Our models consider gas heating and cooling in a viscously evolving disk and solve for the gas temperature and flow hydrodnamics in a simple 1D analysis. We find that the FUV and optical photons from the star are responsible for removing most of the mass of the disk from the outer edge, whereas EUV and X-rays dominate the inner disk evolution. Gaps may be created in the disks under favourable condtions, and can thus affect any ongoing planet formation. We derive disk lifetimes due to photoevaporation and viscous evolution and discuss the implications on planet formation and disk evolution.

Poster #78: The Spitzer c2d Survey of Weak-Line T Tauri Stars III: Transitional Disks.

Zahed Wahhaj
Institute for Astronomy, Manoa, HI

We present Spitzer 3.6 to 70 um photometry of 160 weak-line T Tauri stars (WTTS) in the Chamaeleon, Lupus, Ophiuchus and Taurus star formation regions, all of which are within 200 pc. For a comparative study, we also include 22 classical T Tauri stars. Spitzer sensitivities allow us to robustly detect the photosphere in IRAC bands (3.6 to 8 um) and the 24 um MIPS band. In the 70 um MIPS band, we are able to detect dust emission brighter than roughly 40 times the photosphere. These observations represent the first large WTTS survey longward of the L band, and reveal the frequency of outer disks (r $>$ 3 AU) around WTT stars. We find a disk frequency of 40% for on-cloud WTTS and those separated from their parent clouds by less than 1 degree in projection. However, the disk frequency for WTTS with greater separation is $\sim$ 8% similar to value reported in the first paper in this series (Padgett et al. 2006). Cieza et al. (2007) reported that the on-cloud WTTS had an excess rate of $\sim$ 20%. However, when we include the 70 um detections, this rate increases considerably. We find an average WTTS disk rate of 25% when including all objects within 6 degrees of the cloud. WTTS exhibit spectral energy distributions (SED) that are very diverse, spanning the range from Class II to Class III. In fact, 10% of WTTS SEDs correspond to optically thick CTT-like disks, 15% are transitional disks with inner holes of various sizes, and 75% show no detectable dust within 20-40 AU of the star. However, our sensitivity limits do not allow us to detect disks more tenuous than the debris disk, β Pictoris (fractional luminosity = 2×10^{-3}).

Poster #79: Placing our Solar System in Context:Results from the FEPS Spitzer Legacy Science Program

Lynne Hillenbrand
Caltech

We present results from the Formation and Evolution of Planetary Systems (FEPS) Spitzer Legacy Science Program (Meyer et al., 2006). FEPS obtained Spitzer observations of 336 sun-like stars with ages from 3 Myr to 3 Gyr, constructing spectral energy distributions (SEDs) from 3-160 microns and obtaining for a subset of the stars medium resolution mid-infrared spectra. The SEDs yield constraints on the geometric distribution and mass of dust while the spectra enable a search for emission from gas in circumstellar disks, both as a function of stellar age. Our main goals were to study the transition from primordial to debris disks at ages $<$ 100 Myr, to determine the lifetime of gas-rich disks in order to constrain theories of Jupiter-mass planet formation, and to explore the diversity of planetary architectures through studies of debris disk diversity. We summarize here the results including: 1) the lifetime of inner disks emitting in the IRAC bands from 3-30 Myr (Silverstone et al. 2006); 2)

limits on the lifetime of gas-rich disks from analysis of a IRS high resolution spectral survey (Pascucci et al. 2006; Pascucci et al. 2007), 3) detection of warm debris disks using MIPS 24/IRS as well as HST follow-up (Hines et al. 2006, 2007; Meyer et al. 2008); 4) physical properties of old, cold debris disk systems detected with MIPS 70 (Hillenbrand et al. 2008); and 5) exploration of the connection between debris and the presence of radial velocity planets (Moro-Martin et al., 2007). A synthesis of final results from our program can be found in Carpenter et al. (2008, submitted).

Poster #80: The Dust Composition of Transitional Disks

Manoj Puravankara
University of Rochester

Dust composition analysis of the Spitzer IRS spectra of some 200 youngstars in the three nearby star forming regions of Taurus, Chamaeleon I, and Ophiuchus indicates that an overwhelming majority of these classII objects have crystalline grains in the protoplanetary disks surrounding them. The crystalline dust mass fraction in these disks ranges from a few percent to more than 90%. 'Transitional disks' - disks with inner holes or gaps - are among the objects which show very low crystalline dust content. The IRS spectra of most transitional disks show pristine silicate profiles, very similar to the interstellar silicate profile. This is surprising, as transitional disks are thought to be more evolved than typical T Tauri disks, for which we find evidence for significant crystallization to have occured. The low crystalline dust content of transitional disks argues for a connection between disk structure and dust crystallization and has important implications for disk evolution.

Poster #81: Even Less Gas in the AU Mic Debris Disk

Alexis Brandeker
Stockholm Observatory

AU Microscopii is a member of the beta Pictoris moving group with an edge-on debris disk similar to the one around beta Pictoris. While circumstellar gas has been detected around beta Pictoris, none has so far been found around AU Mic. We here present a high spectral resolution (R$\sim$150000) search for circumstellar absorption of Ca I and Ca II against AU Mic, using bHROS at Gemini South. No absorption is found, implying an upper limit of gaseous Ca $\sim$1000 times lower than previous best estimates.

Poster #82: Observations of Cool Dusty Debris and Scattered Light in Disks – Characterization Beyond Infrared Data

Ricky Nilsson
Stocklholm Observatory

Previous observations with IRAS and ISO, and ongoing observations with Spitzer and AKARI have lead to the discovery of over 200 debris disk candidates, based on detected far-IR excess emission. In order to constrain the properties of these systems, e.g., to accurately determine the dust mass, temperature, and radial extent, follow-up observations in the submillimeter wavelength region is needed. Nearby debris disks could also be spatially resolved in the optical, using coronagraphy and techniques for contrast enhancement. Here we present recent results from 870-micron measurements targeting candidate stars in the beta Pictoris Moving Group, using the Large APEX BOlometer CAmera (LABOCA) on the 12-m APEX telescope, on Llano de Chajnantor, Chile. In addition to interesting results on the well-known beta Pictoris disk itself, a first detection of cold extended dust around HD 181327 was made. We also give an account of an ongoing project using the polarizing coronagraph PolCor2 on the 2.6-m Nordic Optical Telescope (NOT) for resolving nearby dusty disks in scattered light.

Poster #83: The Nearest Herbig Ae Star Transitional Disks

Carol Grady
Eureka Scientific and GSFC

The shape of this IR spectral energy distribution (SED) has been used to infer the degree of dust grain growth and settling in protoplanetary disks and to distinguish between disks which are geometrically flat, those with constant opening angle, and flared disks. Flared disks are expected to be gas-rich, and concentrated among the younger systems lacking evidence of grain growth and settling, and in those with higher current accretion rates. However, transitional disks with dust deficits in the inner disk have similar SEDs to flared disks. By combining SED data, disk outer radius measures, and the radial surface brightness of the disk in scattered light, we test the hypothesis that the majority of Herbig Ae star disks detected in scattered light have flared disks. Instead, we find that the majority of these disks are flatter structures. Low current accretion rates sampled by FUSE FUV spectra further suggest that these disks are the nearest intermediate-mass transitional disks.

Poster #84: Characterizing Dusty Disks Around Solar-Like Stars in Sco-Cen

Christine Chen
Space Telescope Science Institute

We have obtained Spitzer Space Telescope IRS observations of 18 solar-like stars with MIPS 24 and 70 micron excesses in the Scorpius-Centaurus OB association with estimated ages of 3 - 20 Myr; and MIPS SED mode observations for a subset of 11 stars. IRAC and MIPS photometric surveys of 10-15 Myr old associations indicate that the dusty disks in Sco-Cen may be experiencing the onset of the debris phase. While the silicate emission bands possess diverse strengths indicating the presence of grains with a variety of sizes and crystalization fractions, the dust in the majority of systems is cold and/or large similar to that found in debris disks. We reproduce the 5-90 micron SEDs assuming thermal emission from olivine, forsterite, and water ice grains located in a ring with a surface density distribution Sigma proportional to r$^{-1.5}$, similar to that inferred from scattered light observations of debris disks.

Poster #85: X-ray Photoevaporation-Starved T Tauri Accretion Disks

Jeremy Drake
SAO

A new analysis of disk accretion onto T Tauri stars in Orion reveals an inverse correlation between the mass accretion rate and X-ray luminosity of the central star. These results confirm in detail earlier hints that accreting stars have generally lower X-ray luminosities than non-accretors. Current thinking posits that accretion somehow suppresses, disrupts or obscures coronal X-rayactivity. Here, we suggest that the opposite might be the case: the rate of inflow in T Tauri disks is modulated by photoevaporation of the disk by X-ray heating by the parent star. We present the results of our Orion analysis and compare these to predictions from state-of-the-art calculations of EUV-X-ray driven photoevaporation ofT Tauri disks.

Poster #86: The Masses of Transition Circumstellar Disks: Observational Support for Photoevaporation Models

Lucas Cieza
IfA / University of Hawaii

We report deep Sub-Millimeter Array (SMA) observations of a sample of 25 Pre-Main-Sequence (PMS) stars that show evidence for inner disk evolution (i.e., decreased levels of near- and mid-IR excess and/or weak accretion). These observations measure the mass of the cold outer disk (r $\sim$20-100 AU)across every evolutionary stage of the inner disk (r $<$ 10 AU) as determined by the IR Spectral Energy Distributions (SEDs). We find that only targets with high mid-IR excesses are detected and have disk masses in the 1-5 M$_{Jup}$ range, while most of our objects remain undetected to sensitivity levels of M$_{DISK}$ $\sim 0.1 - 1$M$_{Jup}$. To put these results in a more general context, we collected publicly available data to construct the optical to millimeter wavelength SEDs of over 130 additional PMS stars. We find that the

near-IR and mid-IR emission remain optically thick in objects whose disk masses span 2 orders of magnitude($\sim$0.5-50 M_{Jup}). Taken together, these results imply that, in general, inner disks start to dissipate only after the outer disk has been significantly depleted of mass. This provides strong support for photoevaporation being one of the dominant processes driving disk evolution.

Poster #87: New M Dwarf Debris Disk Candidates in NGC 2547

Jan Forbrich
SAO

With only six known examples, M-dwarf debris disks are rare, even though M dwarfs constitute the majority of stars in the Galaxy. After finding a new M dwarf debris disk in a shallow mid-infrared observation of NGC 2547, we present a considerably deeper Spitzer-MIPS image of the region, with a maximum exposure time of 15 minutes per pixel. Among sources selected from a previously published membership list, we identify nine new M dwarfs with excess emission at 24 micron tracing warm material close to the snow line of these stars, at orbital radii of less than 1 AU. We argue that these are likely debris disks, suggesting that planet formation is under way in these systems. Interestingly, the estimated excess fraction of M stars appears to be higher than that of G and K stars in our sample. In addition to the imaging data, we also discuss mid-infrared spectroscopic data of one of these sources, acquired with Spitzer-IRS.

Poster #88: When Do Gaseous Debris Disks Form Rings?

Daniel Jontof-Hutter
University of Maryland

Debris disks with gas may be subject to a clumping instability that could have created the rings observed in transitional disks HR 4796A and HD 141569. We examine this instability in the light of recent observations of the gas disk of Beta Pictoris. We consider the effects on this instability of gas heating by photo-electric effect on dust grains, gas drag on dust grains, atomic line emission, and heat loss to dust grains by conduction.

Poster #89: Metallicities of Young Open Clusters with Debris Disks

TalaWanda Monroe
Indiana University

We present first results of an optical ground-based spectroscopic program of young

open clusters, including metallicities and radial velocities of F and G dwarf cluster members. Our multi-object spectrograph observations from WIYN-Hydra and Magellan-MMFS complement MIPS 24 micron observations of 18 northern and southern clusters in the age range of 3 to 200 Myr, which were examined for excess MIR emission. The aim of this program is to consider the role that stellar metallicity may play in debris disk frequency and longevity.

Poster #90: Resolved Debris Disk Emission around Eta Tel: A Young Solar System or Ongoing Planet Formation?

Laura Churcher
Institute of Astronomy, University of Cambridge

Over half of the A star members of the 12 Myr-old Beta Pictoris moving group (BPMG) show significant excess emission in the mid-infrared, several million years after the proto-planetary disk is thought to have dispersed. Theoretical models suggest this peak may coincide with the formation of Pluto-sized planetesimals in the disk, stirring smaller bodies into collisional destruction. Here we present resolved mid-infrared imaging with T-ReCS of the disk of Eta Tel (A0V in the BPMG) and consider its implications for the state of planet formation in this system. Modelling indicates that the extension arises from an edge-on disk of radius $\sim$24 AU, but that $>$50% of the 18um emission comes from an unresolved dust component at $\sim$4 AU. The radial structure of the Eta Tel debris disk is reminiscent of the asteroid and Kuiper belts in the Solar System, suggesting that this is a young Solar System analogue. However, for an age of 12 Myr, both the radius and dust level of the extended cooler component are also consistent with self-stirring models in which case the hot dust component may arise in massive collisions due to ongoing terrestrial planet formation.

Poster #91: Pre-transitional Disks: The Missing Link for Planet Formation in Disks

Catherine Espaillat
University of Michigan

In their initial stages of formation planets should interact with the accretion disk surrounding the newborn star, clearing the material around themselves and leaving behind an observational signature in the form of gaps in the primordial disk. Stars with inwardly truncated disks have been detected with Spitzer IRS spectra and are now labeled as "transitional disks." While planet formation can create the inner hole in these disks, other formation mechanisms such as photoevaporation or the magneto-rotational instability can account for this type of clearing as well. Our analysis of IRAC broad-band photometry and IRS spectra has now isolated the earliest stages of planet formation in the disk. This new class of "pre-transitional

disks" has an inner optically thick disk separated from an outer optically thick disk by an optically thin gap. In LkCa 15, one of these proposed pre-transitional disks, detailed modeling of the spectral energy distribution demonstrated that although the near-infrared fluxes could be understood in terms of optically thick material at the dust sublimation radius, an alternative model of emission from optically thin dust over a wide range of radii could explain the observations as well. To unveil the true nature of LkCa 15's inner disk we obtained a near-infrared spectrum using SpeX at the IRTF. We report that the excess near-infrared emission above LkCa 15's photosphere is a black-body continuum at the dust destruction temperature, similar to the excess found in full disks. This excess can only be due to an optically thick disk around the star. This is the first confirmation of an inner primordial disk in an object with a separated outer disk. Physical mechanisms that have been presented to explain disk clearing in transitional disks can now be tested with this new class of disk; forming planets emerge as the most likely explanation.

Poster #92: Mid-infrared Spectra of the Transitional Disks of the Orion A Cloud

Kyoung Hee Kim
University of Rochester

We present 5-40 micron Spitzer Infrared Spectrograph spectra of the transitional disks in the Orion A molecular-cloud complex. Transitional disks – T Tau stars with little excess at short infrared wavelengths but excesses similar to ordinary Class II YSOs at longer wavelengths – are thought to owe their distinctive spectral energy distributions (SEDs) to wide central holes or gaps in YSO disks. Here we extend our study of these objects in the nearest star-forming regions to the Orion clouds, a sample twice as large as that in the Tau-Aur-Cha-Oph regions. We compare the SEDs of transitional disks with the median SED of Class II YSOs in Orion A, and assess the disk structures and properties with simple models. We also compare the characteristics of the transitional disks in Orion A with those found in the nearest clouds, to shed light on differences in the evolution of these objects in the variety of star-forming environments found in Orion. Equipped with the IRS spectra of the largest sample of transitional disks identified so far, it is now possible to look for statistically significant trends between disk structure and other properties of the transitional disk systems, which are important to understand the mechanisms responsible for the creation of central clearing or gaps in protoplanetary disks.

Poster #93: A Spitzer Search for Evolved Disks in Taurus

Caer-Eve McCabe
Caltech

We report the initial results of a search for evolved disk candidates, objects with colors intermediate between those of stars and class II pre-main-sequence objects, in the 44 square degree region covered by the Taurus Spitzer Legacy survey. Two separate color criteria are applied: (1) an IRAC [3.6]-[4.5] vs. [5.8]-[8.0] search on objects with 2MASS Ks $<$ 14.5 mag, and (2) a [3.6]-[8.0] vs. [3.6]-[24] search. Combined, these search criteria provide a sample of $\sim$190 objects, including known T Tauri stars, brown dwarfs, galaxies, red giants, and previously unknown sources. All known extragalactic and non-pre-main-sequence objects were removed. Likely extragalactic contaminants were identified through investigation of the 2MASS, IRAC and MIPS color planes, along with a visual inspection of the SDSS and CFHT images. The resulting sample of nearly 2 dozen evolved disk candidates are shown, only two of which are previously known transition/evolved disks (V819 Tau, LkCa 15). One third of these candidates show strong evidence for the presence of an evolved disk around a young star - the remaining two thirds are complicated by uncertainties in either pre-main-sequence status, cloud membership, or multiplicity, each of which is discussed. Follow-up spectroscopy on the previously unknown objects in the Taurus field has begun; we present near-infrared Keck/NIRSPEC spectra of a new mid-M type star with a clear UV excess and evidence for an evolved disk.

Poster #94: A New High-Contrast Imaging Program at Palomar

Sasha Hinkley
Columbia University

In July 2008, a new integral field spectrograph and a diffraction limited, apodized-pupil Lyot coronagraph was installed behind the adaptive optics system at the Hale 200-inch telescope at Palomar. This instrument serves as the basis of a long-term observational program in high-contrast imaging. The technical goal is to utilize the spectral nature of speckle noise to overcome it. The coronagraph alone will achieve an initial dynamic range of 10^{-4} to 10^{-5} at 1 arcsecond, without speckle noise suppression. Initial work indicates that spectral speckle suppression will provide significant improvement over this. Such sensitivity provides detection and low resolution spectra of young planets of several Jupiter masses around nearby stars. Priority targets will include those stars brighter than 8th magnitude and visible from the Northern Hemisphere with known circumstellar disks and planets, and those younger than 1 Gyr. In addition, several hundred survey stars within 25 pc will form the body of the target list. The spectrograph has a spectral resolution of 30-100 across the J and H bands (1.05 - 1.75 microns). The image plane is subdivided by a 200 x 200 element micro-lenslet array with a plate scale of 21 mas per lenslet, diffraction-limited at J-band. Our spatial resolution is twice that afforded by infrared HST observations, with an inner working angle 5 times smaller than HST can achieve through PSF subtraction. Moreover, through follow-up observations of Spitzer targets with a previously detected infrared excess (FEPS etc), this ground-based effort will complement the ongoing Spitzer mission. The addition of the integral field spectrograph will enable spatially resolved spectroscopic study of any imaged disks,

complementing the coronagraphic observations of the disk structure. This system is the first of a new generation of apodized pupil coronagraphs combined with high-order adaptive optics and integral field spectrographs (e.g. GPI and SPHERE).

Poster #95: Thermal Emission from a Newly Resolved Debris Disk

Michael Fitzgerald
LLNL

We report the discovery of an extended disk surrounding the A2IV star HD 131835, a young (∼10-20 Myr) star at 110 parsec and a likely member of the Upper Centaurus Lupus moving group. We have spatially resolved the disk in thermal emission at 11.7 and 18.3 microns with the T-ReCS instrument on Gemini South. The images show extensions indicating the disk is seen at an inclination near edge-on, with a PA of 55 degrees. In both bands, the disk ansae are detected out to sensitivity limits at ∼100-150 AU. The morphology of the 18.3 micron image reveals a warp in the outermost regions, deviating ∼30 degrees from the inner disk. Spatially unresolved excess above the stellar photosphere is also detected in both bands, which can be explained by a source of parent bodies interior to ∼35 AU. Subtraction of this unresolved component suggests differing color temperature between the resolved ansae. In turn, this indicates the presence of dynamical processes that affect the azimuthal dependence of the grain size distribution.

Poster #96: Variability of Disk Emission in Transitional Disk Systems

Karen Collins
University of Louisville

Spectral energy distributions (SEDs) of pre-main-sequence (PMS) stars are commonly used as a diagnostic of disk structure and to measure the successful fit of a circumstellar disk model to the target environment. However, assembling a full set of SED data relevant to the study of a circumstellar environment requires observations from UV to millimeter wavelengths, necessitating observations by multiple facilities and typically resulting in multiple epochs of data being stitched together to cover the wavelength range. We investigate the variability of disk emission from the Herbig F star SAO 206462, discuss adjustments to model parameters to fit the "low" and "high" states, and suggest possible physical explanations. We are conducting a more extensive investigation of transitional disk systems (HD 100453A and other objects) to examine the prevalence of the disk emission variability phenomenon. We also emphasize the importance of the Spitzer IRS and IRAC data base and the warm Spitzer IRAC mission to this project.

Poster #97: Infrared Emission from Ionized Gas in Disks

David Hollenbach
NASA Ames Research Center

Young solar mass stars produce relatively high luminosities in EUV (extreme ultraviolet- 13.6 eV $< h\nu <$ 100 eV) and X-ray ($h\nu >$ 100 eV) photons. These photons heat and ionize the surface of the disk. The EUV photons completely ionize the very top surface region and heat it to about 10,000 K. The X-rays, typically dominated by roughly 1 keV photons, penetrate deeper and heat a partially ionized layer to temperatures greater than about 1000 K. We provide a parameter study of the infrared line spectra produced by ionized species in disks as a function of the EUV and X-ray luminosities, and the EUV spectral shape. Strong lines include [NeII] 12.8 um, [NeIII] 15.6 um, and [ArII] 7.0 um, although we also include estimates of the fine structure lines of [SIII], [SIV], and [OIII] and recombination lines of hydrogen. Comparisons are made with Spitzer data.

Poster #98: From Spitzer to Herschel: Predictions for Debris Disk Gas Emissions

Yanqin Wu
University of Toronto

Several studies have established that there are trace amount of gas in dusty debris disks. This gas is likely not primordial, but arise from dust grains. The very environment of this gas – next to a bright star and embedded among dusty particles – can heat it up to high temperatures, mostly through photoelectrons knocked out from dust grains. For debris disks around early type stars (A-F type), the gas mostly radiates its heat via infrared atomic cooling lines like OI 63 micron, CII 157 micron lines. We calculate the thermal, ionization and excitation balances of this trace gas. For beta Pic like debris disks, the strongest infrared cooling lines have luminosities of order 10^{-7} solar luminosities and are detectable by Herschel. This then allows us to study the chemical composition of the trace gas – and by inferrence, the chemical make-up of the extra-solar Kuiper belts.

Day 4 Oral Presentations

Invited Review
Debris disk census from 5 Myrs to 5 Gyrs

John Carpenter
Caltech

As an extension of the IRAS and ISO heritage, the Spitzer Space Telescope has conducted a comprehensive census of the debris disk phenomenon around nearby stars. I will review the large number of surveys that have been conducted with Spitzer and summarize the observed properties of debris disks around main sequence stars. In particular, I will emphasize i) how the frequency and luminosity of debris disks varies with spectral type and stellar age; ii) the range of dust temperatures in debris systems; and iii) the relationship of debris disks to extrasolar planets.

Planetary Systems around Close Binary Stars: The Case of the Very Dusty, Sun-like, Spectroscopic Binary BD+20 307

Ben Zuckerman
UCLA

Field star BD+20 307 is the dustiest known main sequence star, based on the fraction of its bolometric luminosity, 4%, that is emitted at infrared wavelengths (Song et al 2005; Rhee et al 2008). The particles that carry this large IR luminosity are unusually warm, comparable to the temperature of the zodiacal dust in our solar system, and their existence is likely to be a consequence of a fairly recent collision of large objects such as planets or planetary embryos. BD+20 307 is now known to be a $\sim$3.4 day spectroscopic binary composed of two nearly equal solar-mass stars (Weinberger 2008; Zuckerman et al 2008). We have obtained and analyzed data from all three Spitzer instruments (Weinberger et al 2008). The spectral energy distribution indicates that the dust is confined to a rather narrow region in semi-major axis; there is no evidence for hot dust near the stars, nor for cold dust in a region analogous to the Sun's Kuiper Belt. The Spitzer IRS data enable a great improvement in modeling the composition of the dust particles beyond what was possible based on only ground-based spectra (Song et al 2005). Initially BD+20 307 was thought to be a youthful star (hundreds of Myr old, Song et al 2005), in the final stages of planet formation. However discovery of its binarity and concomitant consideration of a variety of age indicators, lead to a very different conclusion – the star is likely to be at least one Gyr old (Weinberger 2008; Zuckerman et al 2008). Probably the dust around this close binary star has nothing at all to do with planet formation and everything to do with some major catastrophic event that recently took place near 1 AU in a mature planetary system.

Dust Grain Processing in Keplerian discs around Post-AGB Binaries

Clio Gielen

Institute of Astronomy, KULeuven

Studies of circumstellar discs generally focus on proto-planetary discs around young stellar objects. In this contribution, however, we present our ongoing study of stable Keplerian discs around evolved objects. By combining a wide range in observational data and techniques, (optical photometry, interferometry, radial velocity monitoring and optical and infrared spectroscopy), we show that stable compact dusty discs are indeed commonly found, but likely only around post-AGB binaries. In this contribution we focus on our detailed mineralogy study, based on high quality Spitzer-IRS and TIMMI2 spectra. In all sampled stars, the dust is oxygen rich, with avariable, but very high degree of crystallinity. Features of the Mg-rich end members of olivine and pyroxene, namely forsterite and enstatite, dominate the dust spectra. Both cool and hot crystalline dust grains must be present to produce the observed dust emission features. Our 2D SED-modelling shows that the presence of acomponent of large grains is needed to account for the 850 micron flux. This grain growth, together with the high crystallinity, is evidence for efficient dust processing in these circumbinary discs. We end with a more detailed comparison between the dust processing around young stellar objects and around evolved binaries. Our study appears to indicate that the chemico-physical processes in the discs of evolved binaries are very similar to those governing in proto-planetary discs around young stellar objects.

Invited Review
Debris Disk Dynamical Theory

Mark Wyatt
IoA, University of Cambridge

The last few years have seen a dramatic increase in both the quantity and quality of information on debris disks. Photometric surveys show how debris disks evolve and high resolution studies of individual objects provide detailed information on disk structure. Emerging from this wealth of data is the realisation that despite the diversity of dust structures seen in different systems, the underlying model of a planetesimal belt being ground into dust through collisions and being perturbed by an adjacent planetary system provides an excellent description of many systems. However, there is a growing number of examples that defy this simple model leading to the conclusion that stochastic processes may be at play in some systems and that the appearance of debris disks can provide information not just about the underlying planetary system, but also about planet formation processes that could be ongoing in these systems. This talk will review the theory through which debris disk structure and evolution is interpreted, showing how the observations have been used to constrain the underlying physical processes, and identifying the outstanding issues.

How Extrasolar Planetesimals Show Up in Spitzer Data

Torsten Löhne

Astrophysical Institute Jena

One of the major goals to study debris disks is to constrain various properties of their main mass reservoir, the planetesimal populations. However, models are needed in order to link these invisible planetesimals to the observable dust they are thought to produce. We employ our collisional code, ACE, interpret results by means of an analytic model and compare them to available observational data for G-type stars, including Spitzer/MIPS results from various datasets. The aim is to find out, which planetesimal properties can be constrained (i) from the statistics of fractional luminosity decay with age and (ii) from the observed SED of one or another particular disk. Regarding the first question, our results suggest that the observed decay in the dust luminosity is directly linked, among other parameters, to the primordial size distribution of planetesimals set at their accretion epoch. For individual disks, we show how SEDs may help not only to constrain the locations but also the masses of parent planetesimal belts; we find the observed excesses to be compatible with dust steadily produced in massive and large Kuiper belt analogs.

Diversity of Debris Disk Structures - Combining Resolved Imaging and Spectral Energy Distribution Models

Kate Su

Steward Observatory, University of Arizona

While existing Spitzer observations of debris disks show a wide range of diversity in disk morphologies and spectral energy distributions (SEDs), the majority of debris disks are not resolved, resulting in very few direct constrains on disk structures and properties. Progress in high fidelity reductions and an improved understanding of the Spitzer Point Spread Functions have enable us to resolved many more nearby systems at 24 and/or 70 micron. A better reconstruction of the disk structures can be drawn by combining detailed SEDs, composed of Spitzer broad-band (MIPS 24 and 70 micron) photometry and spectroscopy (IRS and MIPS-SED), and resolved imaging. I will present the detailed models of these newly resolved systems to study the diversity of debris disks.

Invited Review
Spatially Resolved Debris Disk Studies - Present and Future

Karl Stapelfeldt
JPL / Caltech

Nearby debris disks provide the best opportunity to image the structures of solar systems like our own. Since the original IRAS discovery of the "Fabulous Four" resolved debris disks, studies at submm, infrared, and optical wavelengths have brought the number of resolved systems to nearly 20. In addition to establishing disk inclinations and position angles, imaging detections break the degeneracy between dust grainsize and asterocentric distance in thermal equilibrium models - thereby establishing the physical scale of extrasolar Kuiper Belts. These studies have directly measured disk central holes, warps, and asymmetries that may be related to planetary perturbers. Imaging searches have placed limits on the mass/luminosity of these putative planetary companions. The cases of epsilon Eridani and Fomalhaut will be specifically highlighted. Future imaging with Herschel; coronagraphs on the repaired HST; ALMA; JWST; and mission concepts such as TPF/Darwin (or their precursors) has great potential to expand the number of resolved debris disks and thus our understanding of nearby planetary systems.

Exploring Planetary Debris Disks at Millimeter Wavelengths: First Detection & Mapping with CARMA

Holly Maness

UC Berkeley

The morphology of planetary debris disks provides the principal evidence required to advance our understanding of their structure and evolution. Although some disks have been mapped in the visible, these images trace sub-micron grains, whose dynamics are dominated by radiative and drag forces. In contrast, millimeter observations reveal large grains primarily influenced by gravity. Therefore, such observations offer the most promising way to probe mean-motion and secular resonances excited by unseen exoplanets. However, despite their importance in understanding these systems, few resolved millimeter debris disk observations currently exist, largely owing to the limited sensitivity and angular resoution of the previous generation of facilities. High resolution observations with the new Combined ARray for Millimeter Astronomy (CARMA) provide the exciting possibility of increasing the number of resolved millimeter systems, thereby serving as an important stepping stone to ALMA. With this motivation, we are running a CARMA program to map relatively bright debris disks. To date, CARMA has contributed three new maps, doubling the number of successful interferometric debris disks observations. I will discuss our team's contributions to these new detections, specifically the recent 1.3-mm mapping of HD-32297 and 49-Ceti. With a sub-arcsecond beam, the HD-32297 detection represents the highest angular resolution millimeter debris disk observation made to date. The resulting map shows an asymmetric structure, perhaps pointing to a planetary induced resonance. The 49-Ceti map, on the other hand, reveals an extended ring of large grains previously only suggested by the SED. These observations, in conjunction with Corder & Carpenter's exquisite map of HD-107146, attest to CARMA's ability to efficiently detect and map these objects. In this context, I will briefly address our future plans to develop a larger scale program with CARMA, following the upcoming receiver and correlator upgrades.

Hot Dust in Debris Disks

Rachel Akeson
NASA Exoplanet Science Institute

The size and radial distribution of dust in debris disk systems can be used to infer the location of the large dust-generating bodies and to explore the dynamics of these systems. Near-infrared interferometers provide a unique observational probe of the dust within the central arcsecond and recent high precision observations have revealed excesses at the 1-2% level at 2.2 microns from some early type main sequence stars. These excesses are most consistent with a hot (T$>$1000 K) dust component very close to the central star. We present new interferometry observations from the Palomar Testbed Interferometer at 1.6 microns to constrain the morphology of the near-infrared excess and discuss the connections between the near and mid-infrared emitting material.

Invited Review
Studies of Star Formation and Circumstellar Disks with the Spitzer Warm Mission

Stephen Strom
NOAO

Through existing studies of star-forming regions, Spitzer has created rich databases which have already profoundly influenced our ability to understand the star and planet formation process on micro and macro scales. However, it is essential to note that Spitzer observations to date have focused largely on deep observations of regions of recent star formation associated directly with well-known molecular clouds located within 500 pc. What has not been done is to explore to sufficient depth or breadth a representative sample of the much larger regions surrounding the more massive of these molecular clouds. Also, while there have been targeted studies of specific distant star forming regions, in general, there has been little attention devoted to mapping and characterizing the stellar populations and star-forming histories of the surrounding giant molecular clouds (GMCs). As a result, we have yet to develop an understanding of the major physical processes that control star formation on the scale or spiral arms. Doing so will allow much better comparison of star-formation in our galaxy to the star-forming complexes that dominate the spiral arms of external galaxies. The power of Spitzer in the Warm Mission for studies of star formation is its ability to carry out large-scale surveys unbiased by prior knowledge of ongoing star formation or the presence of molecular clouds. The Spitzer Warm Mission will provide two uniquely powerful capabilities that promise equally profound advances : high sensitivity and efficient coverage of many hundreds of square degrees, and angular resolution sufficient to resolve dense groups and clusters of YSOs and to identify contaminating background galaxies whose colors mimic those of young stars.

Invited Review
Future Science Directions in the Study of Circumstellar Disks

Ewine F. van Dishoeck
Leiden Observatory/MPE Garching

Spitzer has hugely contributed to our understanding of disk structure, composition and evolution, from the youngest deeply embedded stages to the oldest debris disk phase. Thanks to its large and in many cases unbiased surveys, (nearly) complete samples of disks in different environments (different clouds, stellar mass, ...) and ages have been defined. These sample will form the input for many follow-up studies with future facilities, at higher spatial and/or spectral resolution. Key questions raised by Spitzer will be discussed in the context of future facilities, in particular the Herschel Space Observatory, JWST, ALMA and ELTs. Complementary theory and laboratory data will continue to be crucial to analyze the data and understand the steps leading to new planetary systems.

Day 4 Topical Posters

International Ballroom, Sunday through Thursday

Poster #99: Survey of Nearby FGK Stars at 160 microns with Spitzer

Angelle Tanner
JPL

The Spitzer Space Telescope has advanced debris disk science tremendously with the detection of over thirty disks around nearby AFGK and M stars at 24 and 70 micron with MIPS and 8-34 micron with IRS. Here, we present 160 micron observations of a sub-set of these stars. At these wavelengths, the stellar photospheric emission is negligible and any detected emission corresponds to cold dust ($\sim$20K) at distances of 100-200 AU from the star. The Spitzer 160 micron detections suffer from the added complication of a light leak next to the star's position whose flux is proportional to the near-infrared flux of the star. We are able to remove the contamination from the leak and report the 160 micron fluxes for those stars detected at this wavelength. We find four stars (HD 10647, HD 207129, HD 115617 and AU Mic) with excesses at 160 micron and use this additional photometry to constrain the properties of the debris disks around them.

Poster #100: Cold debris disks around M-dwarfs

Jean-Francois Lestrade
Observatoire de Paris CNRS

We have conducted a search for cold debris disks around M-dwarfs at λ =1.2mm by imaging the fields of more than 50 targets with the bolometer array MAMBO at the IRAM 30m radiotelescope. By combining with other recent surveys conducted with MIPS/Spitzer and SCUBA/JCMT, we establish that the detection rate of cold debris disks around M-dwarfs is 4.8 (+3.0/-2.6) %, which is lower than for solar and A-type dwarfs for the same level of sensitivity (fractional dust luminosity 1.E-5 - 1.E-4). We shall discuss mechanisms that may imped formation or survival of debris disks around M-dwarfs.

Poster #101: The Historical Distribution of Zodiacal Dust Levels and the Detection of Exo-Earths

Marc Kuchner
NASA Goddard Space Flight Center

Seafloor sediment 3He concentrations trace the flux of interplanetary dust onto the

Earth. We compile existing data on these concentrations from ∼80 Myr ago to the present and examine the implications of this data for missions like the Terrestrial Planet Finder (TPF) that aim to find habitable extrasolar Earth-like planets. We find that the dust levels have a log normal distribution, implying that 95% of solar analogs should have zodiacal dust concentrations in the range of 0.6–2.6 zodis, to the extent that these stars have asteroid belts similar to our own in terms of collision statistics. Our results can serve as a null hypothesis for future surveys of exozodiacal dust and provide minimum requirements for planning TPF.

Poster #102: Dynamics of Dust Particles in Binary Systems

Jens Rodmann
ESA/ESTEC

Recent Spitzer observations demonstrate that debris disks are also common around main-sequence binary systems (Trilling et al. 2007). These findings indicate the presence of planetesimal belts around binary stars and on-going collisional activity in them, mostly likely driven by larger planetary bodies. While several people have conducted dynamical studies on the stability of planetesimals/planets in binary systems (e.g. Holman & Wiegert 1999), the dynamics of dust particles has not been investigated so far. Here we present first results from our debris disk model MODUST (Rodmann 2006) that includes the relevant non-gravitational forces (radiation pressure, Poynting-Robertson effect, stellar winds). Two different model scenarios will be presented: (1) circumstellar debris disks, where the binary separation is larger than the disk radius, and (2) circumbinary debris disks, where the disk surrounds the two stars.

Poster #103: A Search for Debris Disks Based on AKARI Mid-infrared All-sky Survey

Hideaki Fujiwara
University of Tokyo

After the IRAS observations, main-sequence stars that have circumstellar debris disks and thus show infrared excess have been discovered. Since debris disks are thought to be the final stage of planet formation, it is very important to property and evolution of debris disks statistically. AKARI is the first Japanese infrared astronomical satellite dedicated for infrared astronomy. The mid-infrared survey was carried out with the 9 micron and 18 micron bands using the Infrared Camera (IRC) with higher sensitivity and spatial resolution than IRAS. We are carrying on the unbiased survey of debris disk candidates that show mid-infrared excess by using the AKARI/IRC mid-infrared all-sky survey data. So far, we have identified a number of new debris disk candidates that show large 18 micron excess. In this presentation, we will show the initial results of the debris disk survey.

Poster #104: Observing Debris Discs with Herschel

Bruce Sibthorpe
UK Astronomy Technology Centre

We present an insight into the data characteristics expected from the planned observations of debris discs using the Herschel space observatory. This poster focuses specifically on the quality and depth of the data. We analyse and compare the influence of the various observing modes on confusion noise and data quality, and present the optimal mode for the both the PACS and SPIRE instruments.

Poster #105: Spitzer-Resolved Disks around Solar-Type Stars

Geoffrey Bryden
JPL

Despite its small size, Spitzer has been unexpectedly successful at resolving the thermal emission from nearby debris disks. We present 70um images of 11 such disks around solar-type stars. Measurements of disk sizes break some of the degeneracy inherent in unresolved SEDs, placing much better constraints on the dust grain sizes and overall disk mass. With typical disk radii of $\sim$100 AU, the dust is much hotter than the local blackbody temperature, suggesting that small ($<$10um) grains dominate the thermal emission.

Poster #106: The Mysterious IR Excesses in RS CVn Binaries

Marco Matranga
SAO

One of the most remarkable properties sometimes attributed to RS CVn binaries is evidence of infrared excess, which is thought related to the presence of circumstellar matter. The existence of this non-stellar component in the flux distribution of such a class of object has been the subject of considerable controversy. Within current scenarios explaining IR excess around late type stars, RS CVn should not have any: they represent a significantly older population than the $\sim$ 400 Myr dusty disk lifetime, with typical ages of 1 Gyr or more. Moreover, they have not undergone any evolutionary period during which substantial mass loss is expected. If the IR excesses in close binary stars are real, they are caused either by long-lived dusty disks, an unexpected episode of significant mass loss at the subgiant Hertzsprung gap phase, or mass loss through stellar winds and coronal mass ejections at rates much higher than currently assumed. However, incorrect assessment of the binary photospheric SED might also be to blame. Here we present the results of a Spitzer investigation into the putative IR excesses of 9 RS CVn systems, and a discussion of the results in the context of these competing scenarios.

Poster #107: The Rings of Epsilon Eridani

Massimo Marengo
Harvard-Smithsonian CfA

Our Spitzer Space telescope and Caltech Submillimeter Observatory new images and spectra have revealed an unexpected view of the epsilon Eridani debris disk. We found a complex rings system, characterized by gaps and radial changes in composition and grain size. This data provides new clues on the structure and the dynamics of the epsilon Eridani planetary system, and suggests the presence of new planets in addition to the known radial velocity giant.

Poster #108: Debris Disks and Exo-planet Habitability

Jane Greaves
University of St Andrews

A census of Spitzer results for nearby Solar analogues shows that around 20 percent of these stars host debris at much greater levels than in the Solar System, and sometimes at ages older than the Sun. Any terrestrial planets could therefore be heavily bombarded for billions of years. We discuss the fraction of systems in which life might never evolve to an advanced state, in particular modelling the rate of catastrophic impacts (e.g. removing the crust and oceans) on exo-Earths in the Habitable Zone. This rate depends on the comet population and the interaction with giant planets, both of which can now be infered from data. We also consider how Spitzer upper limits constrain the fraction of 'clean' systems and estimate the distance to the closest 'safe system' for life to evolve around a Solar-type star.

Poster #109: The Evolution of Warm Debris Disks: Implications for Recent Collisions

Peter Abraham
Konkoly Observatory of the Hungarian Academy of Sciences

We report on the results of a Spitzer program devoted to studying debris disks around F-type stars. The motivation of the program was to outline disk evolution effects in a constrained stellar mass range, and also to make the bridge between the major Spitzer surveys of debris disks around A-type and G,K-type stars. We observed 78 F-type stars with IRS and MIPS, all of them with previous indications for infrared excess from IRAS or ISO. The observed debris disk population shows a large variety in dust temperatures. In this contribution we report the discovery of four warm debris disks, which significantly increases the number of such systems known. Based on the fractional luminosity and age, three out of the four warm debris systems are consistent with a steady state disk evolution picture. The infrared luminosity of the fourth system, HD 169666, is too high to be explained by a steady state evolution, but it is consistent with a recent collisional cascade. This picture is reinforced by the prominent silicate emission features present in the IRS spectrum. The observed diversity of warm debris disks is consistent with a simple evolutionary picture: collisional cascades inject large amounts of small grains into the disk; with time, smaller grains are removed faster by radiation pressure resulting in the decay of the infrared excess and the weakening of the silicate features. Transient warm disks, like HD 169666 may be the closest analogues yet to the Late Heavy Bombardment in our Solar System. Such systems could be primary targets for follow-up observations searching for planets.

Poster #110: M Dwarf Debris Disks

Peter Plavchan
IPAC/Caltech

Among the numerous M dwarfs sampled by Spitzer in the nearest 25 pc, AU Mic remains a unique M dwarf with its debris disk, infrared excess, 12 Myr age, flaring, and X-ray activity. We present preliminary results from 24 micron and 70 micron MIPS (Multiband Imaging Photometer for Spitzer) observations of 22 X-ray saturated M dwarfs like AU Mic out to a median distance of 32 pc. From these initial observations, we have discovered 3 new M dwarf debris disks identifiable from their infrared flux excess. We place our results in context with a sample of 70 A through M-type dwarfs selected with common youth indicators such as lithium abundance, moving group membership, chromospheric activity, and rapid rotation.

Poster #111: Binaries Among Debris Disk Stars: IRAS vs Spitzer

David Rodriguez
UCLA

We have gathered a sample of 112 main-sequence stars (ages older than 10 Myr) with known infrared excesses. Our sample includes stars within 100 pc and ranges from spectral types B8 to K2, though most (89) are A or F stars. Most of these excesses were discovered with IRAS and many have been confirmed with MIPS on Spitzer. We are collecting published information and making our own measurements

on these stars to determine if they are binaries or multiple star systems. With this we will obtain a measure of how often binary stars contain debris disks and determine whether properties such as the average dust temperature or L(IR)/L(star) are sensitive to the presence of companions. This work will be compared with the Trilling et al. (2007 ApJ, 658, 1289) Spitzer-based study of debris disks in main-sequence binary systems.

Poster #112: A Search for a Global Infrared Evolution of Debris Disks

Carolina Chavero
National Observatory of Rio de Janeiro

By means of infrared color-color diagrams we explore and describe new sequences representing a global evolution of debris disks around low mass stars. Our search begins with an IRAS distribution of the twenty spatially resolved debris disks with published images known up to now. We found a sequence that follows an age order of their central stars from spectral types A to M. In a second step, we found that non-resolved IRAS debris disks candidates follow the same pattern distribution as the resolved ones. This property permits to derive approximative the ages of these candidates in an independent way. The next step uses Spitzer color fluxes of resolved and non-resolved debris disks and a more actual distribution is found. In any case, both IRAS and Spitzer sequences are in favor for a global steady state collisional evolution of debris disks in an inside-outside direction. First, the inside dust zone emitting at $\sim$ 24 um is dissipated rapidly in the interval period between 8 and $\sim$ 100 Myr. Then, a very slow dissipation of the farther disk dust zone radiating at $\sim$ 70 um characterize the evolution of debris disks from $\sim$100 Myr up to $\sim$ 7 Gyr. A comparison of the debris disk sequence with the distribution of the younger primordial disks around classical T Tauris suggests, from the IR point of view, that the younger debris disks at 8 Myr and some at 11 Myr represent a kind of "bridge" between these two populations. On the other hand, by considering the spatially resolved disks around A-type stars, we found that the true fractional luminosities follow a behavior of t$^{-1.8}$ up to the age of $\sim$ 400 Myr. This is somewhat steeper than the respective apparent fractional luminosities t$^{-1.4}$ in which the disk inclination have not been considered.

Poster #113: False Signs of Debris Disks: Stellar-ISM Interactions

Andras Gáspár
Steward Observatory, University of Arizona

The discovery of the bow shock at delta Velorum, originating from the star's interaction with its surrounding ISM (Gaspar et al. 2008), shows that such interactions can imitate debris disks, even within the Local Bubble. What are the general conditions

for such effects and how common are they? We will report the discovery of ten new bow shock candidates, of which one is within 35 parsecs, as is delta Velorum. We discuss the physical properties of these systems and the observations needed to distinguish them from real debris disk excesses. We also estimate their number statistics with a nearly complete sample within a distance of 45 parsecs.

Poster #114: Mid-IR Spectra of Dust Debris around A and late B type Stars: Asteroid Belt Analogs and Power-Law Dust Distributions

Farisa Morales
JPL

Using the Spitzer/IRS spectrometer low-resolution modules covering wavelengths 5-to-35 microns, we observed 52 main-sequence A and late B type stars previously thought from Spitzer/MIPS photometry to have excess infrared emission at 24 microns above that expected from the stellar photosphere. The mid-IR excess is confirmed in all cases but two. While prominent spectral features are not evident in any of the spectra, we observed a striking diversity in the overall shape of the spectral energy distributions. Most of the IRS excess spectra are consistent with single-temperature blackbody emission, suggestive of dust located at a single orbital radius–a narrow ring. The typical dust temperature of i$\sim$200 K corresponds to an orbital radius of $\sim$10 AU. Thirteen stars however, have dust emission that follows a power-law distribution, $F_\nu \propto \lambda^\alpha$, with exponent α ranging from 1.0 to 2.9. The warm dust in these systems must span over a greater range of orbital locations – an extended disk. All of the stars have also been observed with Spitzer/MIPS at 70 microns, with 30 of the 50 excess sources detected (S/N$>$ 3). Most 70 microns fluxes are suggestive of a cooler, Kuiper Belt-like component that may be completely independent of the Asteroid Belt-like warm emission detected at the IRS wavelengths. Less than half blackbody-like debris systems have MIPS 70 microns detections; thirteen sources with IRS excess emission fit by a continuous disk model, however, are all detected at 70 microns (two above, four on, and seven below the extrapolated power-law), suggesting that the mid-IR IRS emission and far-IR 70 microns emission are somehow connected to each other. Overall, the observed blackbody and power-law thermal profiles reveal debris distributed in a wide variety of radial structures that do not appear to be correlated with spectral type or stellar age.

Poster #115: A Survey for Habitable Zone Debris Disks with Nulling Interferometry: Complimentary Observations to Spitzer

Wilson Liu
University of Arizona

The complex nature of debris disks necessitates the use of complementary obser-

vations at different wavelengths and spatial scales in order to form a complete understanding. We have observed six nearby main sequence stars (alpha CrB, alpha Lyr, beta Leo, gamma Ser, epsilon Eri, and zeta Lep) with the MMT Observatory using nulling interferometry in the N-band. Using this technique, we are sensitive to debris in the "habitable zones" of these systems, which are located at closer separations from the star (a few AU) than longer wavelength observations of cold debris by Spitzer (tens to hundreds of AU). Although no positive detection of habitable zone material was made with our observations, we can place firm upper limits for dust density in these systems, in the range of several hundred zodis. In several systems (e.g., Vega, beta Leo, epsilon Eri) this contrasts with a high density of dust in the outer systems detected by Spitzer. We discuss physical processes which could lead to the dust distribution observed in these systems.

Poster #116: Emission Properties of an Eccentric Disk around HD69830

Matthew Payne
Institute of Astronomy, University of Cambridge

Spitzer observations of HD 69830 have revealed an excess of emission relative to the stellar photosphere between 8 and 35 microns, but no excess at 70 microns. Subsequent radial velocity observations have also revealed a system of 3 close-in Neptune-mass planets in the same system. We investigate the potential for a long-lived eccentric planetesimal disk to explain these observations. We perform n-body simulations of the system formation to understand the likelihood of an eccentric disk forming and then combine this work with models of the collisional evolution of such disks, in order to understand their long-term spectral emission properties.

Poster #117: Evolving Debris Disks: Connecting Extrasolar Disk Observations to those of the Solar System.

Andrew Shannon
University of Toronto

Around 15% of FGK stars have detectable infrared excess in the 70 micron Spitzer band. These excesses have brightnesses of order $10^{-5} - 10^{-3}$ of the stellar luminosities and decays slowly as the stars age. They arise from thermal re-radiation of small dust particles (microns to millimeters) orbiting the stars at distances similar to that of our Kuiper belt. Larger bodies must be present in these disks to continuously produce the dust particles. These bodies are intimately related to late stages of planet formation, but their properties can only be indirectly inferred. In contrast, the largest bodies in our Kuiper belt are observed, while its associated dusty disk is below detection and is believed to be thousand times less luminous. We investigate the origin of this brightness difference. Our study reveals the underlying conditions

in observed debris disks, as well as providing a strong constraint on the history of the Kuiper belt.

Poster #118: Next Generation Debris Disk Surveys following Spitzer

Neil Phillips
Institute for Astronomy, University of Edinburgh

Debris disks are short-lived belts of dust and debris formed from the collisions of planetessimals. These disks can be observed by their thermal emission in the mid/far-IR and sub-mm. Recently surveys with Spitzer's MIPS instrument have been greatly increasing our knowledge of debris disk incidence and properties. This contribution will describe forthcoming large ($\sim$500 systems) surveys of nearby stars at longer wavelengths using SCUBA-2 on the JCMT, and PACS+SPIRE on Herschel. Longer wavelengths give improved sensitivity to cool disks like our Kuiper Belt, and probe larger dust grains. In particular I will present the SCUBA-2 Unbiassed Nearby Stars Survey (SUNSS), and the DEBRIS Herschel Key Project, both of which target A-M type main sequence stars.

Poster #119: Spitzer Observations and Dynamical Modeling of Two Multi-planet Systems with Dust

Amaya Moro-Martin
Princeton University

In the search for Solar system analogs, the study of planetary systems with multiple planets and dust emission (the later implying the presence of asteroid-like or kuiper belt-like planetesimals) is of critical importance. Only five of these systems have been identified so far: HD69830, HD10647, HD 82943, HD38529 and HD128311. This presentation summarizes the study of the later two. HD 38529 is a post-main sequence G8III/IV star (3.5 Gyr old) with a planetary system consisting of at least two planets having Msini of 0.8 MJup and 12.2 MJup, semimajor axes of 0.13 AU and 3.74 AU, and eccentricities of 0.25 and 0.35, respectively. HD 128311 is a K0 star (ages in the literature vary from 0.6 to 6 Gyr) with a planetary system consisting of at least two planets having Msini of 2.19 MJup and 3.22 MJup, semimajor axes of 1.1 AU and 1.76 AU, and eccentricities of 0.25 and 0.17, respectively. Spitzer/MIPS observations of both stars show spatially unresolved excess emission above the stellar photosphere at 70 um with a signal-to-noise ratio (S/N) of 4.7 for HD38529 and $\sim$4 for HD128311, while no dust excess is detected at 24 um. Spitzer/IRS observations shows a small excess at 33 um (S/N=2.6) and no excess $<$30 um for HD38529, and no excess at any wavelength for HD128311. For these two stars, we discuss the distribution of the potential dust-producing planetesimals from the study of the dynamical perturbations of the two known planets, considering in particular the effect

of secular resonances, and from the modeling of the spectral energy distributions. We find that the configuration might resemble that of the Jovian planets + Kuiper Belt in our Solar System.

Poster #120: Debris Disks Among the Shell Stars: Insights from Spitzer

Aki Roberge
NASA GSFC

Shell stars are a class of early-type stars with narrow absorption lines in their spectra that appear to arise from circumstellar gas. This observationally defined class contains a variety of objects, including evolved stars and classical Be stars. However, some of the main sequence shell stars harbor debris disks and younger protoplanetary disks, though this aspect of the class has been largely overlooked. We surveyed a set of main sequence shell stars for cool dust using Spitzer MIPS and found four additional systems with IR excesses at both 24 and 70 microns. This indicates that the stars have both circumstellar gas and dust, and are likely to be edge-on debris disks. Our estimate of the disk fraction among nearby main sequence shell stars is 48% $\pm$ 14%. We here discuss the nature of the shell stars and present preliminary results from ground-based optical spectroscopy of the survey target stars. We will also outline our planned studies aimed at further characterization of the shell star class.

Poster #121: DUNES: DUst disks around NEarby Stars

Carlos Eiroa
Universidad Autonoma de Madrid

DUNES is a sensitivity-limited Herschel Key Programme that aims at finding and characterizing faint exo-solar analogues to the Edgeworth-Kuiper Belt in an unbiased, statistical sample of nearby FGK main-sequence stars. Our sample is volume-limited (distances $<$ 20 pc) and spans a broad range of stellar ages - from $\sim$0.1 to $\sim$10 Gyr. All stars with known extrasolar planets within that distance are included; additionaly, some M- and A-type stars will be observed in colaboration with the DEBRIS Herschel OTKP, so that the whole sample covers a decade in stellar mass from 0.2 to 2 solar masses.

Poster #122: The Detectability of Exo-Earths and Super-Earths Via Resonant Signatures in Exozodiacal Clouds

Christopher Stark
University of Maryland/NASA Goddard Space Flight Center

Directly imaging extrasolar terrestrial planets necessarily means contending with the astrophysical noise of exozodiacal dust and the circumstellar resonant structures created by extrasolar planets in exozodiacal clouds. Using a custom tailored hybrid symplectic integrator we have constructed 120 models of resonant structures created by exo-Earths and super-Earths on circular orbits interacting with collisionless steady-state dust clouds around a Sun-like star. Our models include enough particles to overcome the limitations of previous simulations that were often dominated by a handful of long-lived particles, allowing us to quantitatively study the contrast of the resulting ring structures. We used these models to estimate the mass of the lowest-mass planet that can be detected through observations of a resonant ring for a variety of assumptions about the dust cloud and the planet's orbit. Our simulations suggest that planets with mass as small as a few times Mars' mass may produce detectable signatures in debris disks at circumstellar distances greater than 10 AU.

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