Transformational Science with ALMA: Through Disks to Stars and Planets

June 22-24, 2007
North American ALMA Science Center
and National Radio Astronomy Observatory Headquarters
Charlottesville, Virginia, USA

Abstract Book

Pages

Program

Friday, 22 June

Session 1 - Chair: Crystal Brogan

09:00 - 09:10 Welcome - Fred K. Y. Lo
09:10 - 09:40 (I) *"ALMA: Project Overview & Status"* - Tony Beasley
09:40 - 10:10 (I) *"Keynote Talk"* - Anneila Sargent

Session 2 - Chair: Doug Johnstone

10:10 - 10:40 (W) *"Observations of Cores, Fragmentation and the Earliest Observable Stages of Protostellar Disks"* - Jes Jorgensen

BREAK 10:40 - 11:10

11:10 - 11:25 (C) *"Tricks of Resolution and Dynamics: A Disk-Like Object that Isn't"* - Brenda Matthews
11:25 - 11:55 (W) *"Unraveling the Envelope and Disk: The ALMA Perspective"* - Leslie Looney
11:55 - 12:10 (C) *"Understanding the Disk-Envelope Connection"* - Shantanu Basu
12:10 - 12:30 Group Discussion

LUNCH 12:30 - 13:45 (on site in the 3^{rd} Floor Library)

Session 3 - Chair: John Bally

13:45 - 14:15 (W) *"The Origin of Outflows"* - Stephane Guilloteau
14:15 - 14:30 (C) *"Massive Outflows from the Submillimeter Array and Spitzer Infrared Observations"* - Keping Qui
14:30 - 15:00 (W) *"The Dynamics of Competitive Accretion"* - Paul Clark
15:00 - 15:15 (C) *"Massive Protoclusters: Keys to Understanding Massive Star Formation"* - Todd Hunter

BREAK 15:15 - 15:45

Session 4 - Chair: Dick Crutcher

15:45 - 16:15 (W) *"Accretion, Mixing, and Grain Growth in Protostellar Disks: Observing Magnetized Turbulence with ALMA"* - Neal Turner
16:15 - 16:30 (C) *"Magnetic Braking and Protostellar Disk Formation"* - Zhi-Yun Li
16:30 - 17:00 (W) *"Molecular Lines and Thermal dust Emission as Tools to Investigate the Physical Structure of Disks"* - Anne Dutrey
17:00 - 17:15 (C) *"Observations of Disks Associated with High Mass Young Stars"* - Qizhou Zhang
17:15 - 17:45 Group Discussion

18:15 - 20:30 Reception at NTC hosted by NRAO Director. Includes tour of North America ALMA Front End Integration Center

Saturday, 23 June

Session 5 - Chair: Lynn Matthews

09:00 - 09:30 (W) *"Massive Protostellar Disks: Formation, Properties, and Observables"* - Mark Krumholz
09:30 - 09:45 (C) *"MHD Waves as a Source of Heating in Accretion Disks"* - Aline Vidotto
09:45 - 10:15 (W) *"ALMA Observations of Irradiated Proto-Planetary Disks"* - John Bally
10:15 - 10:30 (C) *"X-rays and Protoplanetary Disks"* - Eric Feigelson

BREAK 10:30 - 11:00

Session 6 - Chair: Rémy Indebetouw

11:00 - 11:30 (W) *"Tracing the Role of Magnetic Fields in Protostellar Disks"* - Dick Crutcher
11:30 - 11:45 (C) *"Understanding the Role of Magnetic Fields in the Star Formation Process though Polarimetry"* - Ram Rao
11:45 - 12:10 Group Discussion
12:10 - 12:30 Poster Advertisements - 1 min/1 slide each

LUNCH 12:30 - 13:45 (on site in the 3^{rd} Floor Library)

Session 7 - Chair: Anthony Remijan

13:45 - 14:15 (W) *"Chemistry in Disks – an Observational Perspective"* - Chunhua Qi
14:15 - 14:30 (C) *"Distributions of Hot Molecules in Young Circumstellar Disks"* - Hideko Nomura
14:30 - 14:45 (C) *"On the Kinematics of Photoevaporating Disks: The Case of MWC349"* - Jesus Martin-Pintado
14:45 - 15:15 (W) *"Complex Carbon Chemistry in Disks"* - Paul Woods

15:15 - 15:30 Group Photo in Front of NRAO Building - Pat Smiley

BREAK 15:30 - 16:00

Session 8 - Chair: Leonardo Testi

16:00 - 16:30 (W) *"Debris Disks - Structure and Evolution"* - Jane Greaves
16:30 - 16:45 (C) *"The Solar System: the Closest Debris Disk"* - Dave Jewitt
16:45 - 17:00 (C) *"Spitzer Space Telescope Debris Disks"* - Michael Werner
17:00 - 17:15 (C) *"A Resolved Molecular Gas Disk around 49 Ceti"* - David Wilner
17:15 - 17:45 Group Discussion

17:45 - 18:45 Drinks and Poster Viewing at NRAO

19:00 - 21:00 Workshop Dinner at the Garden Room sponsored by the UVa Astronomy Department - After Dinner Talk by Paul Vanden Bout "*The Senator from Chile*"

Sunday, June 24

Session 9 - Chair: Claire Chandler

09:00 - 09:15 *"Introduction to the NAASC"* - Crystal Brogan
09:15 - 09:30 *"Introduction to ALMA User Software"* - Debra Shepherd
09:30 - 10:00 *"UVa Computing/Simulation Initiative Discussion"* - Nicole Radziwill

Session 10 - Chair: Al Wootten

10:00 - 10:15 (C) *"Young Brown Dwarfs and ALMA"* - Subhanjoy Mohanty

BREAK 10:15 - 10:45

10:45 - 11:15 (W) *"Signatures of Planets and Their Formation in Circumstellar Disks"* - Sebastien Wolf
11:15 - 11:30 (C) *"Theory Based Guide To Observing Planets - Fragmentation And Gaps"* - Hannah Jang-Condell
11:30 - 11:45 (C) *"Extra Solar Planet Detection with ALMA"* - Alice Quillen
11:45 - 12:10 (I) *"ALMA and the Widefield Infrared Survey Explorer (WISE)"* - Mike Skrutskie
12:10 - 12:30 Group Discussion

LUNCH 12:30 - 13:40 (on site in the 3rd Floor Library)

Session 11 - Chair: Lee Mundy

13:40 - 14:10 (W) *"Setting the Stage for Planet Formation: Grain Growth in Circumstellar Disks"* - Leonardo Testi
14:10 - 14:35 (I) *"Observations of Disks with the EVLA: What Will it Do for You?"* - Claire Chandler
14:35 - 15:00 (I) *"Synergy with Herschel"* - Brenda Matthews
15:00 - 15:25 (I) *"Synergy with JWST"* - Alycia Weinberger

BREAK 15:25 - 15:45

15:45 - 16:30 Closing Discussions

Talks

ALMA: Project Overview & Status

Tony Beasley (ALMA/JAO)

Richard Hills (JAO/ALMA)
Rick Murowinski (JAO/ALMA)
Alison Peck (JAO/ALMA)
Massimo Tarenghi (JAO/ALMA)

Presentation: Invited

The Atacama Large Millimeter/submillimeter Array (ALMA) is an international radio telescope under construction in the Atacama Desert of northern Chile by North America, Europe, Japan, Chile and associated partners. ALMA will be situated on the high altitude Chajnantor plateau, which provides excellent atmospheric transmission over the instrument wavelength range of 0.3 to 3 mm. ALMA will be comprised of an array of 12-m diameter antennas arranged in a multiple configurations ranging in size from 0.15 to $\sim$ 14 km, and a closely-packed array of 7-m diameter antennas known as the Atacama Compact Array. This combination will provide sensitive interferometric and total-power astronomical information over a broad range of angular scales. High-sensitivity full-polarization spectral-line and continuum measurements between all antennas will be available from two flexible digital correlators.

Array control and support will primarily be carried out at the Operations Support Facility at 3000m, and ALMA Regional Centers in the US, Europe and Japan will provide the scientific portals for the use of the instrument. In this talk we will review the construction project status, and describe upcoming major events in 2007/2008.

Keynote

Anneila Sargent (Caltech)

Presentation: Invited

Observations of Cores, Fragmentation and the Earliest Observable Stages of Protostellar Disks

Jes Jorgensen (Harvard-Smithsonian Center for Astrophysics)

Presentation: Wish

One of the most important unanswered questions in our understanding of low-mass star formation is how circumstellar disks form and evolve. Many previous studies have focused on the properties of disks around revealed young stellar objects, yet disks are likely formed in the deeply embedded, “Class 0”, stages of low-mass protostars and their properties related to the physical and chemical structure of the innermost regions of the centrally condensed envelopes surrounding such young stars. For a long time these “youngest” disks have remained elusive, partly because they are deeply embedded in cold envelopes (extincting the emission from the central star+disk system) and partly because of their small sizes ($<$ a few hundred AU $\sim$ 1–2$''$ for nearby star forming regions). With high angular resolution observations from present-day (sub)millimeter interferometers and high sensitivity mid-infrared observations from the Spitzer Space Telescope we can now characterize the inner envelopes and disks of young stellar objects in these earliest evolutionary stages.

In this talk I will present an overview of studies of the small scale structure of deeply embedded low-mass protostars, focusing in particular on observations from the Protostellar Submillimeter Array Campaign and Spitzer Cores to Disks Legacy surveys. With the high angular resolution submillimeter observations we find evidence for disks containing 0.01–0.1 $M_\odot$ of mass, typically 1–10% of the mass of their ambient envelopes. In some cases these disks are even resolved with $\sim$ 100 AU sizes underscoring the rapid build-up of the disks through these early stages. Contrary to previous expectations, many of these sources are also detected at wavelengths as short as a few μm. These mid-infrared observations constrain the extinction toward the central star and in some cases the region where the “envelope stops and disks start” at radii of a few hundred AU. I will discuss the prospect for future ALMA observations of these deeply embedded stages and touch upon some of the issues that need to be addressed before we can take full advantage of those possibilities.

Tricks of Resolution and Dynamics: A Disk-Like Object that Isn't

Brenda Matthews (Herzberg Institute of Astrophysics)

Presentation: Contributed

The identification of high-mass protostellar objects and associated accretion disks is one of the most active areas of star formation research. This field is likely to make rapid progress in the era of ALMA. I will present the results of a BIMA array study of a high-mass star-forming region, IRAS 23033+5951 (Reid & Matthews 2007). We find evidence of a high-mass analogue to a Class 0 source as well as a potential high-mass starless core. Most intriguing is the detection of an extremely massive, rotating, disk-like object. Based on its scale and geometry, we argue that this object cannot be a protostellar disk, but is instead a remnant of the parent molecular cloud.

Many potential high-mass regions and young stellar objects will be identified in dust emission with SCUBA-2, a new submillimeter camera soon to arrive at the James Clerk Maxwell Telescope. Like IRAS, SCUBA-2 will identify dust condensations and identify targets for ALMA. I will give a brief update to SCUBA-2's schedule and discuss two star formation surveys: the Galactic Plane Survey and the Gould Belt Survey.

Unraveling the Envelope and Disk: The ALMA Perspective

Leslie Looney (University of Illinois)

Lee Mundy (University of Maryland)
Hsin-Fang Chiang (University of Illinois)
Konstantinos Tassis (University of Chicago)
Woojin Kwon (University of Illinois)

Presentation: Wish

A comparison of our Solar System to those planets found in radial velocity planet searches illustrates the diversity of planetary systems. There is an exciting question in the origins of that diversity: Is our system representative of typical planet formation or is it unusual? This question can be addressed by observational and theoretical star formation. However, the answer requires a more in-depth understanding of the initial conditions in and evolution of circumstellar disks than is available currently. One of the main obstacles in tracking disk evolution is that the initial disk is deeply embedded within the large-scale circumstellar envelope. Even with the spatial frequency filtering available with today's interferometers, the residual components of the envelope emission can still produce apparent compact structures, even without compact disk emission. ALMA will change this landscape dramatically.

In this talk, we will examine the current observations of Class 0 and Class I objects and the constraints on the youngest disks. In particular, we will emphasize the difficulties of disentangling the envelope emission from the disk emission: dangers, pitfalls, and successes. With the increase in observational wavelength, sensitivity, dynamic range, and image fidelity, we will show how ALMA will reveal the earliest disk properties and evolution. In addition, we will also discuss the impact such observations will have on collapse models and how ALMA will provide hard constraints on the details of theoretical modeling of both the envelope and disk structures.

Understanding the Disk-Envelope Connection

Shantanu Basu (University of Western Ontario)

Presentation: Contributed

New numerical simulations make it possible to study the formation of disks deep within collapsing core envelopes and follow their evolution for several Myr. The large dynamic range of spatial scales and temporal evolution afforded by these simulations have helped to reveal the importance of envelope accretion to the protostellar accretion process. In two recent papers (ApJ, 2005, 633, L137, and ApJ, 2006, 650, 956) we have shown that disks can be driven into recurring gravitational instability. These instabilities lead to the formation of clumps that eventually spiral into the central protostar. The episodes of intense accretion can manifest themselves as FU Ori outbursts. This 'burst mode' of accretion can last for the first $\sim$ Myr of evolution, following which a disk can settle into a quiescent phase of residual accretion. During this phase, the accretion can be driven effectively by gravitational torques due to transient nonaxisymmetric density perturbations. The accretion rates are correlated with the masses and initial angular momenta of the parent cloud cores. The observed correlation between mass accretion rate and star mass can be reproduced for plausible initial conditions.

We review work in this field by various groups which is leading to a new understanding that disk evolution must be tied to the properties of the parent core envelope. The observed correlation between accretion rate and stellar mass is likely telling us something about the mass and angular momentum accumulation and evolution in the disks. We compare results of the global gravitational torque model with the predictions of the local alpha viscosity model for disk accretion. Clear distinctions are made where possible between the observational predictions of the two classes of models.

The Origin of Outflows

Stephane Guilloteau (L3AB / OASU Bordeaux)

Anne Dutrey (LAB)
Jerome Pety (IRAM)
Frederic Gueth (IRAM)

Presentation: Wish

Despite many years of studies, the origin of molecular outflows remains a puzzle. Evidence for prompt entrainment by shocks do exist (e.g. HH 211), but usually at significant distances from the star. On the other hand, recent high resolution observations of HH 30 reveal a relatively wide angle cone which is more suggestive of wide-angle wind, perhaps a disk wind. Rotation of the outflow has been searched for as a possible tracer of the outflow origin. A puzzling issue is why are some outflows one-sided, although they are associated with bipolar optical jets? I will discuss how ALMA, by offering the possibility of observing many transitions of different excitation conditions at high angular resolution, can radically change our understanding of the outflow origin.

Massive Outflows from the Submillimeter Array and Spitzer Infrared Observations

Keping Qiu (Harvard-Smithsonian CfA)

Qizhou Zhang (Harvard-Smithsonian CfA)

Presentation: Contributed

We present high resolution observations of outflows in massive star forming regions obtained with the Submillimeter Array and the Spitzer Space Telescope. The detected outflows vary in form from collimated jets to wide angle shells. In the (sub)mm interferometer observations, the morphologies, kinematics and energetics of CO and/or SiO outflows are derived. In the Spitzer/IRAC observations, the outflows are usually prominent in the IRAC 4.5 μm band due to the shocked H_2 emission, while in some cases they can be detected from the scattering light in the short wavelength bands. The complementary (sub)mm and infrared observations help the identification and interpretation of molecular outflows.

The Dynamics of Competitive Accretion

Paul Clark (University of Heidelberg)

Ian Bonnell (University of St Andrews)
Matthew Bate (University of Exeter)

Presentation: Wish

The processes behind the formation of the IMF are still not clear. Some models argue that fragmentation sets the available gas reservoir for each star, while others favour a more chaotic process in which accretion from the whole star forming region sets the stellar masses. Our discussion will compare these two extreme modes of IMF creation, focusing on the dynamics of the gas in each case. Looking at the density and velocity information, we will try to suggest observational signatures of the two processes that will be compatible with the abilities of ALMA. We will also discuss disc survival in the competitive accretion model.

Massive Protoclusters: Keys to Understanding Massive Star Formation

Todd Hunter (NRAO)

Crystal Brogan (NRAO)

Presentation: Contributed

Recent Submillimeter Array (SMA) observations at 1.3 and 0.8mm have revealed the existence of compact clusters of dust continuum sources in a growing number of massive star formation regions. In objects such as NGC6334I and I(N), the multiplicity and separation of the cluster members are similar to the Trapezium stars (10000 AU), suggesting a massive protostellar cluster (or "protocluster"). While some of these protoclusters also host an ultracompact HII region, others do not. In addition, some of the cluster members are associated with hot core molecular line emission, while others exhibit cooler gas. By providing a deeper and sharper view of these protoclusters, ALMA will probe for the accompanying presence of lower mass protostars and will measure the gas temperature and velocity dispersion of the major cluster members. The resulting quantitative study of these clusters should provide important clues to the mechanism of massive star formation.

Accretion, Mixing, and Grain Growth in Protostellar Disks: Observing Magnetized Turbulence with ALMA

Neal Turner (JPL/Caltech)

Takayoshi Sano (Osaka Univ.)
Natalia Dziourkevitch (MPIA Heidelberg)
Karen Willacy (JPL/Caltech)
Sally Robinson (UC Santa Cruz)
Paola D'Alessio (UNAM)

Presentation: Wish

Turbulence driven by magnetic forces plays a central role in protostellar disks. Turbulence transfers angular momentum so that accretion can proceed; mixes material from hot and cold regions into the zone where planets form; and brings grains together to build up larger bodies. Magneto-rotational turbulence requires sufficient ionization of the disk gas, and is absent from a "dead zone" that overlaps the location of the planets in the solar system. The dead zone size is sensitive to the cross-sectional area of the dust grains suspended in the gas, and the outer edge of the dead zone in the minimum-mass solar nebula can lie anywhere between 2 and 60 AU, depending on the abundance and sizes of the grains. The inner edge lies near the dust sublimation line, where amorphous interstellar silicates are reprocessed into crystalline form. Large-scale magnetic fields can drive accretion inside the dead zone even in the absence of turbulence. Outside the dead zone, the turbulent speeds are comparable to the Alfven speed, and are greatest in the surface layers where the density is low and the magnetic fields are strong. Observations of infrared rovibrational lines indicate turbulent speeds in the surface layers of the inner disk that are consistent with the results of 3-D numerical MHD calculations. ALMA will probe the kinematics of gas at a much wider range of radii and depths, enabling detailed tests of our models of ionization chemistry and magnetized turbulence and leading to a great leap in our knowledge of transport inside protostellar disks, with major consequences for understanding planet formation. As examples I will discuss the locations and timescales of grain growth, the position of the snow line and the amount of solid material available to form the cores of the gas giant planets.

Collaborators in the work discussed are Takayoshi Sano (Osaka U.), Natalia Dziourkevitch (MPIA), Karen Willacy (JPL/Caltech), Sally Robinson (UC Santa Cruz), Paola D'Alessio (UNAM), Geoffrey Bryden (JPL/Caltech), Harold Yorke (JPL/Caltech), Augusto Carballido (Cambridge/Caltech), James Stone (Princeton).

Magnetic Braking and Protostellar Disk Formation

Zhi-Yun Li (University of Virginia)

Richard R. Mellon (University of Virginia)

Presentation: Contributed

Disk formation is a fundamental problem in star formation. It is often stated that disks form naturally and inevitably as a result of angular momentum conservation. The angular momentum of the dense core material that collapses to form a (low-mass) star is not conserved, however. Even a magnetic field as weak as a few μG can remove a large fraction of the angular momentum of the collapsing flow, if the field lines are frozen in the matter. In this ideal MHD limit, magnetic fields of strength in the observed range can suppress disk formation completely through magnetic braking. For the all-important disk to appear in the problem of star formation at all, the powerful magnetic brake must come off one way or another. How this comes about is a central issue of disk formation that is still not fully understood.

In this presentation, we review the early work without magnetic fields that supports the popular notion of disk formation as a result of angular momentum conservation. We then show how this notion must be modified, or even abandoned, in the presence of a realistic magnetic field, if the field and matter are well coupled. We will present results from our previous work (Allen, Li & Shu 2003) and especially newly completed, higher resolution calculations (Mellon & Li, in preparation) that illustrate in detail how the magnetic field can extract essentially all of the angular momentum of the core material that collapses to form a star. These calculations strongly suggest that understanding disk formation requires a detailed understanding of the field-matter decoupling, which is also a prerequisite for resolving the longstanding "magnetic flux problem' in star formation. We discuss how non-ideal MHD effects, such as ambipolar diffusion, affect the efficiency of magnetic braking and disk formation in magnetized clouds.

It is important to search for observational evidence for magnetic braking. Such a task is ideally suited for ALMA, given its high angular and spectral resolutions. High angular resolution is required because the braking is expected to impact most the dynamics of the transition region between the disk and the infalling envelope: differential rotation between the two is expected to wind up the field lines, creating an expanding magnetic bubble that may be directly observable. High spectral resolution is desirable because the braking typically drives transonic motions. The well-known accretion shocks above and below a forming disk in the non-magnetic collapse are also expected to be strongly modified in the presence of a realistic magnetic field, with implications for disk chemistry and ice processing. We will discuss these and other observable signatures of disk formation in magnetized clouds.

Molecular Lines and Thermal dust Emission as Tools to Investigate the Physical Structure of Disks

Anne Dutrey (Observatoire de Bordeaux)

Vincent Pietu (IRAM)
Stephane Guilloteau (LAB)

Presentation: Wish

Interferometric observations of abundant molecules like CO and its isotopomers have been used as efficient tools to unveil the complexity of the physical structure of gas in proto-planetary disks. More recently, improvements in sensitivity and angular resolutions have allowed to directly constrain the dust temperature and opacity at mm wavelengths. We will present here the state art of current CO and dust analysis of interferometric data in disks. Using well-known objects (DM Tau, LkCa 15, MWC 480 and AB Aur) which have been observed at sub-arcsecond resolution, we will show the complementary of the CO and dust observations to constrain the thermal and density structure of proto-planetary disks, and in particular the vertical temperature gradient. We will extrapolate this to the ALMA era.

Observations of Disks Associated with High Mass Young Stars

Qizhou Zhang (Harvard-Smithsonian Center for Astrophysics)

Presentation: Contributed

Kinematic signatures of infall and rotation have been seen in both molecular and ionized gas toward massive young stars thanks to high resolution observations. I will review recent results from searches for infall and rotation and the observational properties of massive disks and toroids. I will discuss formation of massive stars through accretion.

Massive Protostellar Disks: Formation, Properties, and Observables

Mark Krumholz (Princeton University)

Presentation: Wish

Competing models for massive star formation make strong predictions about the properties of the disks around massive, accreting protostars, but existing telescopes are unable to observe these environments with enough sensitivity and resolution to test these predictions. I review models of massive star formation and their predictions regarding disks, and I discuss how high resolution ALMA observations may be able to definitively settle some outstanding questions in the theory of massive star formation. I focus in particular on the core accretion model, which recent simulations show naturally produces disks ~ 1000 AU in extent around embedded massive protostars. These disks have a number of distinctive properties, including strong spiral structure and masses that can reach half that of their host star. I present detailed calculations of both dust continuum and molecular line emission from these disks. Simulated ALMA observations of this emission shows that if disks with these properties exist, ALMA should be able to detect and resolve them in quite reasonable integration times.

MHD Waves as a Source of Heating in Accretion Disks

Aline Vidotto (IAG/USP - Brazil)

Vera Jatenco-Pereira (IAG/USP - Brazil)

Presentation: Contributed

The need of a minimum amount of ionization in protostellar accretion disks is necessary for the magneto-rotational instability to take place. This instability is believed to be the mechanism responsible for a magneto-hydrodynamic turbulence that could lead to the accretion observed. In this work we study the role of MHD waves as a source of heating in disks. We analyze if Alfven waves, when damped during their propagation through the disk, can transfer enough energy in order to raise the ionization fraction of the disk. As the disks are composed of dust, we suggest here that the these waves are damped by the dust cyclotron mechanism of damping. In this mechanism when charged dust particles acquire the same (cyclotron) frequency as the waves, a resonance occurs that leads to the damping of the waves. Here, we present a disk model with two heating mechanisms: the "anomalous" viscosity considered in terms of the α-parameterization and the damping of Alfven waves. We vary the space parameters in order to study the second mechanism's behavior. We show that the waves can increase the temperature of the disk and flatten the traditional $r^{-3/4}$ effective temperature profile of the disk. Although they can heat the disk, a simple analysis of the ionization fraction shows that the waves can diminish the quiescent region of disk, but cannot eliminate it.

ALMA Observations of Irradiated Proto-Planetary Disks

John Bally (University of Colorado, Boulder)

Henry Throop (Southwest Research Institute, Boulder)

Presentation: Wish

Young proto-planetary disks are irradiated by UV radiation fields generated either by their central stars (*self-irradiation*) or by nearby massive stars in the parent cluster (*external irradiation*). The presence of the decay products of the short-lived radio-isotope ^{60}Fe in primitive meteorites provides suggestive evidence that our own Solar System formed in close proximity to massive stars. Mass-independent fractionation patterns in oxygen isotopes provides evidence that primitive Solar System materials were extensively processed by strong UV radiation fields.

UV-induced mass-loss, coupled with viscous disk evolution, grain growth, and large-particle sedimentation can lead to the rapid growth of metallicity in protoplanetary disk mid-planes. Gravitational instabilities can then lead to the formation of planetesimals having diameters of a few to tens of kilometers on a dynamical time-scale (Throop & Bally 2005, ApJ, 623, L149; Youdin & Shu 2002, ApJ, 580, 494). Thus, UV irradiation-induced selective removal of light material combined with gravity can therefore help to bypass the thorny problems associated with grain growth from μm-sized dust to large bodies. X-ray and infrared observations of Orions proplyds provide evidence that some photo-ablation flows are indeed metal-depleted, as predicted by this model. UV radiation can photolyze the raw material of disks into complex organic molecules. Simple estimates of process indicate that the flux in typical dense cluster environments ($G_0 = 10^5$) is sufficient to create the entire Solar Systems current inventory of complex organic molecules.

The largest proto-planetary disks in Orion are over $1''$ (500 AU) in radius; those in Taurus have radii of several arcseconds (500 AU). At its highest frequencies, ALMA will eventually resolve angles as small as 10 to 20 milliarcseconds. Thus, large disks within 500 pc of the Sun will be resolved with hundreds resolution elements across their major axes. ALMA will image disks with tens of thousands of individual pixels, each of which contains a spectrum. ALMA will resolve a variety of disk structures including gaps produced by forming giant planets, spiral density waves, and critical photo-evaporation radii, detect direct evidence for grain growth by measuring local variations in the sub-millimeter spectral index, and measure local variations in the gas-to-dust ratio. Additionally, the hundreds of spectral lines that fall within the ALMA bands will enable the direct detections of the snow-line, and measure chemical differences between various zones in proto-planetary disks. The large-isotope shifts in the sub-mm part of the spectrum will enable a direct measurement of the rates of mass-independent fractionation processes such as those induced by UV radiation.

For disks embedded within HII regions, ALMA will characterize the transitions of solids, ices, and gases from the disk mid-plane to the soft-UV induced low-velocity wind, detect the shocks where this flow in compressed above the disk by the ram-pressure of the ionized zone, trace the photo-destruction of various molecules, trace their daughter products, and directly measure the transition of atoms to a fully ionized plasma. Velocity-resolved spectroscopy will enable the measurement of disk rotation curves, hence the masses of their central stars, the acceleration of the radiation-induced winds, the density and velocity jumps at shocks, and trace the kinematics of the flows in the fully-ionized outer zones by means or sub-mm radio recombination lines. ALMA will transform proto-planetary disk evolution and earl-stage planetary system formation from a mostly theoretical subject into a major observational topic.

X-rays and Protoplanetary Disks

Eric Feigelson (Penn State University)

Presentation: Contributed

Planets form in cold circumstellar disks that can not emit X-rays. Nonetheless, X-ray band studies may have profound implications for the physical processes of protoplanetary disks in several ways. Observations of young stellar clusters, such as the recent Chandra Orion Ultradeep Project (COUP), demonstrate that all pre-main sequence stars produce powerful magnetic reconnection flares during the planet formation era. Calculations indicate that the X-rays can penetrate deeply into protoplanetary disks and will be the dominant source of gas ionization. COUP observations of fluorescent line emission in heavy disk stars and soft X-ray absorption in proplyds demonstrate that disk irradiation by X-rays does in fact occur. This may induce MHD turbulence in disk gases, which may substantially affect planetesimal growth and protoplanet migration. X-rays heat the outer dust layers to high temperatures, and induce ion-molecular chemical reactions. Diagnostics of these effects should be accessible to ALMA. X-ray flares or associated shock waves may also affect disk solids by flash melting dustballs into chondrules, and generation generate shortlived radioactive isotopes prevalent in the meteoritic record via spallation from flare energetic particles.

Tracing the Role of Magnetic Fields in Protostellar Disks

Richard Crutcher (University of Illinois)

Presentation: Wish

Magnetic fields likely play a significant role in the formation and evolution of protostellar disks and outflows from disks and/or protostars. We very briefly review the techniques (the Zeeman effect, dust polarization, and spectral-line linear polarization) that will be available to ALMA observers for measuring magnetic fields in protostellar disk environments, discuss the current state of the observational picture, and consider in detail just what observations should be possible with ALMA and the sensitivities that such observations should reach. ALMA will make it possible to study at least the morphologies of magnetic fields in protostellar disks and outflows through linear polarization mapping of dust and spectral-line emission, and Zeeman observations of field strengths may be possible. These polarization observations should lead to significant breakthroughs in our understanding of the role of magnetic fields in this latter stage of the star formation process.

Understanding the Role of Magnetic Fields in the Star Formation Process though Polarimetry

Ramprasad Rao (ASIAA)

Daniel P. Marrone (Dept. of Astronomy and Astrophysics, Univ. of Chicago)
Josep Miquel Girart (Institut de Cincies de l'Espai (CSIC-IEEC), Catalunya-Spain)

Presentation: Contributed

Using the newly installed polarimetry system on the Submillimeter Array, we are able to obtain high resolution ($\sim 1''$) maps of polarized dust emission from regions of active star formation. Two such regions that have been studied are the low mass young stellar objects NGC 1333 IRAS4A and IRAS16293. Both YSOs show ordered magnetic field structure. We can deduce that magnetic field has played an active role in the formation of these young stars. A campaign is underway to map and study additional regions and thus enhance our knowledge of magnetic fields.

Chemistry in Disks – an Observational Perspective

Chunhua Qi (Harvard-Smithsonian Center for Astrophysics)

David J. Wilner (Harvard-Smithsonian Center for Astrophysics)
Geoffrey A. Blake (California Institute of Technology)

Presentation: Wish

In recent years, millimeter-wave interferometers have imaged the gas and dust surrounding over a dozen T Tauri and Herbig Ae stars. These studies improve our understanding of disk physical and chemical structure, providing unique insights into the complicated processes by which planetary systems form. Here we summarize our observational understanding of the chemistry in protoplanetary disks using predominantly results obtained with the OVRO mm array and the Submillimeter Array (SMA). We present high resolution (0.5″ to 5″) (sub)mm interferometric observations of molecules in lines of ^{12}CO, ^{13}CO, $C^{18}O$, HCO^+, HCN and CN towards protoplantary disks around several T Tauri and Herbig Ae stars – TW Hya, LkCa 15, MWC 480, GM Aur and HD 163296. We also report the resolved images of deuterated species DCN and DCO^+ and upper limits to the emission of HDO, D_2H^+ and H_2D^+ from TW Hya, the closest known classical T Tauri Star (d=56 pc). We use an irradiated accretion disk model and two-dimensional radiative transfer calculations to fit the visibility data for various basic disk parameters, including the outer radius R_{out}, inclination angle i, and the fractional abundances of various molecules. The *Chi*-square fitting results have been compared with detailed chemical models to investigate the influence of the gas temperature structure, dust grain growth, and X-ray/FUV emission from the central stars on the radial and vertical distribution of molecules. We find that the intensities of the CO J=2–1, 3–2, and 6–5 lines require substantial CO depletion, as well as higher gas than dust temperatures at large scale heights, due to surface heating. We find strong evidence from the resolved data that DCO^+ is depleted within the inner disk (R<40AU) and increases by an order of magnitude in the outer disk (R>80 AU). This trend is consistent with chemical models, which predict higher deuterium fractionation in the outer disk where low temperatures and high CO depletion prevail. With the existing arrays, especially the SMA, we are starting to constrain the thermal, physical and chemical structure of protoplanetary disks as a function of radius and height, but the inner disk properties (R<20 AU) remain elusive due to limited sensitivity and angular resolution. These inner regions, where planets are thought to form, will be accessible with ALMA.

Distributions of Hot Molecules in Young Circumstellar Disks

Hideko Nomura (Queens University Belfast)

Yuri Aikawa (Kobe University)
Yoshitsugu Nakagawa (Kobe University)
Tom Millar (Queen's University Belfast)

Presentation: Contributed

It is believed that stars and planets are formed from gas and dust in disks accumulated at the center of dense molecular cores. Disk accretion is the essential process which controls evolution of the central star, disk dispersal, and giant planet formation. Some observations, such as Hα line emission, have been proposed as evidence of disk accretion onto the central star. However, some theoretical work has suggested that planet forming region in the disks is magnetorotationally stable, and observational evidence of disk accretion in this region is of great interest.

In this work we investigate the distribution of hot molecules in young circumstellar disks as a tracer of the disk accretion process by making use of the chemical models of the evaporation of icy mantle molecules from dust grains and subsequent gas phase reactions. The mantle molecules, which are formed in the cold dense region near the midplane of the outer disk, evaporate as accretion brings the dust grains into the hot inner disk close to the central star. We have modeled self-consistent density and temperature profiles of the gas and dust, and use time-dependent gas-phase chemical kinetic models to determine the distributions of parent and daughter molecules.

The calculation shows that parent molecules evaporated from dust grains are eventually destroyed and daughter species produced on a time scale of around 10^{4-5} years. As a result, we can use the radial distributions of parent and daughter species to trace the accretion rate in the disks. In addition, we solve the radiative transfer equation and obtain line spectra of molecular emission from the disks. The result shows that the radial distributions of line emission are observable by using high spatial resolution and high sensitivity ALMA observation. Therefore, forthcoming ALMA observation may make it possible to diagnose the disk accretion rate in the planet forming region of young circumstellar disks.

On the Kinematics of Photoevaporating Disks: The Case of MWC349

Jesus Martin-Pintado (DAMIR-Instituto de Estructura de la Materia-CSIC)

Presentation: Contributed

In the last years, it has been recognized that MWC349 is the prototype of a massive protostar surrounded by a photoevaporating disk. The observational properties (strong continuum, recombination line emission and recombination line masers) of this objects makes it an ideal candidate to study key aspects of massive star formation, like the kinematics of the disks and the origin of ionized winds produced by photoevaporation of the disk which might explain the life-time paradox found for ultracompact HII regions.

I will present recent high sensitivity observations of the H30α maser line emission obtained with the Plateu de Bure Interferometer. The relative positions of maser line emission's centroid as a function of the radial velocity has been measured with an accuracy of about 1 mas for the strongest maser features. These data reveal, for the first time, the east-west velocity gradient expected for a rotating disk around MWC349 and velocity gradients perpendicular to the disk due to the evaporation of the disk. These data are in contrast with the photoevaporating disks models which predict that photoevaporation must occur at a radius larger than the gravitational radius where the ionized gas is not confined by the gravitational well of the star. Models of rotating and photoevaporating disks that best fit the new high angular resolution data will be used to constrain the kinematics of the disk and of the photoevaporation processes. This will illustrate the potential of ALMA for studying the properties and the kinematics of the disks around massive stars.

Complex Carbon Chemistry in Disks

Paul Woods (JPL)

Karen Willacy (JPL)

Presentation: Contributed

I will discuss models of carbon chemistry in protoplanetary disks, where molecules range from small carbon-bearing species such as CO to single ring molecules, such as benzene, to larger, multi-ring molecules (PAHs). Benzene is only produced efficiently in regions close to the star, which are unresolved by most present-day telescopes. The presence of benzene in protoplanetary disks may be indicative of the formation of PAHs in situ, rather than their introduction from the interstellar medium. I will discuss the plausibility of this scenario.

I will also look at carbon fractionation, and how the abundance of carbon isotopes varies with location, giving us a tool with which to label different regions of the disk. Assuming a lack of effective mixing, the fractionation in surface regions of the disk reflects that in the protostellar cloud, whereas in the midplane of the disk carbon-bearing molecules are fractionated according to temperature, with CO being enriched in ^{13}C and other molecules being depleted in ^{13}C. There are also photofractionation effects in the intermediate layers of the disk. I will show that the fractionation chemistry in the disk is not sufficient to provide the increase in $^{12}C/^{13}C$ ratio that is seen when comparing Solar System values with values for the local ISM, either at present times or at the time of formation of the solar system. This strongly suggests contamination of the presolar nebula with material from a supernova or massive stars close to the time of its formation.

Debris Disks - Structure and Evolution

Jane Greaves (University of St Andrews)

Presentation: Wish

I will review what is known of the various structures resolved within debris disks around nearby stars. Cavities may reveal clearing by inner planets while clumps within debris rings are attributed to resonant orbits with outer system planets. This is a new technique for pinpointing and studying planets at tens of AU that ALMA will uniquely be able to exploit - potentially also tracking clump orbital motions within timescales of only months. Further, imaging debris rings is the key to understanding why the phenomenon occurs for only some among a group of very similar stars - for example, is debris sporadic after a stirring event, or a result of divergent evolution related to different planetary system architectures? I will discuss the debris properties of nearby stars from a few hundred Myr up to 10 Gyr old.

The Solar System: the Closest Debris Disk

David Jewitt (University of Hawaii)

Presentation: Contributed

The Kuiper Belt is the Sun's own debris disk, and the only one that is close enough for us to directly detect embedded dust parent bodies. The Belt has a normal optical depth near 10^{-7}, consistent with collisional production from the known parents. Remarkably, Kuiper Belt dust has already been directly detected by spacecraft in the outer Solar system. Dust drifts inwards to the terrestrial planet region on a 10^{7} yr timescale, but suffers such extensive collisional destruction on the way that few examples are expected in the stratospheric dust collections. The Jupiter family comets, on the other hand, are macroscopic carriers of matter from the Kuiper belt that clearly survive the journey and provide us with samples of dust trapped in ice since our debris disk formed.

In this short talk I will set out what we know about the Kuiper Belt in a format that is relevant to those who study more remote debris disks. I will include remarks about possible evolutionary scenarios that connect our (very old) debris disk with the (mostly) younger ones detected around other stars.

A Resolved Molecular Gas Disk around 49 Ceti

David Wilner (CfA)

Meredith Hughes (CfA)

Presentation: Contributed

The star 49 Cet (distance 61±3 pc) is one of only 3 A-type stars (of about 1500) in the Bright Star Catalog with a ratio of circumstellar dust luminosity to stellar luminosity > 0.001. Unlike the other two– the famous debris disks beta Pic and HR 4796A– 49 Cet defies classification as a debris disk on account of weak CO emission indicative of molecular gas. We have imaged the CO 2–1 line emission from 49 Cet with the Submillimeter Array at 60 AU resolution and find a highly inclined rotating gas disk, aligned with mid-infrared emission seen at smaller scales. However, there is no detectable CO emission within about 95 AU radius, and there is no detected 1.3 mm continuum emission. The 49 Cet system appears to be in a late transition phase between a gas rich protoplanetary disk and a tenuous, dusty (and virtually gas free) debris disk. We use these data to speculate on the processes responsible for decreases in molecular gas content as disks evolve.

Spitzer Space Telescope Debris Disks

Michael Werner (JPL/Spitzer)

Karl Stapelfeldt (JPL/Caltech)

Presentation: Contributed

Much of the observing time on Spitzer has been devoted to imaging, photometry, and spectroscopy of planetary debris disks. We review the major results of this work, which cover the following topics: Imaging and spectroscopy of the most prominent debris systems; demonstration of the temporal evolution and stochastic nature of disks around A stars; the statistics and character of debris disks around nearby solar type stars; disks fractions in nearby young stellar associations; disks around binary star systems; and identification of crystalline and amorphous silicate minerals in debris disks.

Young Brown Dwarfs and ALMA

Subhanjoy Mohanty (Harvard University)

Presentation: Contributed

I will briefly review the current state of knowledge regarding accretion disks in brown dwarfs (BDs), and the interaction of the disk with the central object. In particular, I will discuss (1) observations of accretion/outflow phenomena in BDs; (2) the dependence of accretion rate ($\dot{M}$) on the central mass, for masses ranging from solar-type stars to BDs; (3) temporal evolution of $\dot{M}$; (4) observations of variability in the accretion line profiles and implications for $\dot{M}$; (5) evidence for disk-locking; and finally (6) role of the central BD in disk evolution, e.g., creation of large inner holes through planetesimal formation and/or photoevaporation. I will then summarize the ways in which ALMA can greatly advance our knowledge of these issues, and thereby shed light on both the differences/similarities in the formation mechanism of stars versus BDs, and the viability of planetesimal formation around BDs.

Signatures of Planets and Their Formation in Circumstellar Disks

Sebastian Wolf (MPI for Astronomy)

Presentation: Wish

The detection of extrasolar planets and planetary systems has enormously stimulated and invigorated the studies of planet formation during the last decade. In particular, a detailed picture of the evolution of circumstellar/protoplanetary disks, which provide the material and environment from and in which planets are expected to form, has been developed. However, the planet formation process itself is in major parts still under discussion. In order to improve our understanding of planet formation and to refine existing hypotheses for the various phases of this process, adequate observational constraints are required.

In this talk studies will be presented which are focused on the observability of selected phases and predicted phenomena of the planet formation process. Moreover, observational consequences of the interaction between (proto-)planets and their environment – the circumstellar disks within which planets are expected to form – are discussed for different stages of the disk evolution.

Core Accretion vs. Disk Instability: Observable Discriminants

Hannah Jang-Condell (Carnegie Institution of Washington)

Presentation: Contributed

I will discuss ways to distinguish between disk instability and core accretion, the two competing paradigms for giant planet formation. Disk instability happens when a massive disk fragments into planet-sized self-gravitating clumps. The disk's structure will be highly perturbed by the formation of the massive clump. Core accretion happens when solid particles collide and coagulate into larger and larger bodies until a body large enough to accrete a gaseous envelope forms – around 10-20 Earth masses. Although this is insufficiently massive to disturb the disk as a whole, the planet core perturbs the disk material immediately in its vicinity. Near-infrared scattered light images only detail activity in the tenuous upper layers of the disk, but submillimeter wavelengths should be able to probe deeper in the disk. A disk undergoing gravitational instability will have a more turbulent structure, while the signature for core accretion should be more localized to the planet's position. In either case, ALMA's high angular resolution will be necessary to observe the detailed structure. ALMA will be a key tool for understanding how and when planets form in circumstellar disks and help settle the debate over whether disk instability or core accretion is the dominant mechanism for giant planet formation.

Extra Solar Planet Detection with ALMA

Alice Quillen (University of Rochester)

Presentation: Contributed

Young circumstellar disks are likely to harbor planets and minor planets. An understanding of the interaction between massive bodies and gaseous or particle disks can lead to the discovery of massive bodies that are indirectly detected. In some cases bodies above a certain mass can be excluded. Bodies inferred to be present in young disks provide strong constraints on and challenges for scenarios of planet and planetesimal formation.

I will cover the ways that the presence, mass and orbital properties of massive bodies can be inferred from high angular resolution observations of circumstellar disks, both young and gaseous and older composed of dust and debris, that will become possible with ALMA. I will emphasize how key observables such as disk and edge thickness, optical depth, gas and dust fraction, disk composition, particle size distribution and morphology impact the dynamical scenarios considered. I will describe ongoing work on 3D simulations that predict the structure of disk edges of transitional disks, and inferred constraints on possible planets residing in these systems. I will describe recent work on collisional/debris disks placing limits on minor bodies in disks like Au Mic and predicting more massive bodies in disks with central clearings such as Fomalhaut. I will summarize efforts to develop the numerical and theoretical framework required to interpret ALMA observations in terms of models incorporating planetesimal and planet formation and associated disk structure.

ALMA and the Widefield Infrared Survey Explorer (WISE)

Michael Skrutskie (University of Virginia)

Presentation: Invited

Following launch in November 2009, the WISE mission will execute a 6-month long survey of the entire sky at wavelengths of 3.3, 4.8, 12, and 23μm with a cryogenically cooled 40cm telescope. The WISE short wavelength bands will have 5-sigma point source sensitivity of $\sim$ 150 μJy while the longer bands will have 5-sigma sensitivity of $\sim$ 1mJy. In relatively short order (6-18 months following the end of the survey) the Infrared Processing and Analysis Center (IPAC) will issue a source catalog containing several hundred million reliable source extractions and an all sky image atlas in each of the bands. WISE will provide significant scientific leverage to address the populations of brown dwarfs in the Milky Way and ultra-luminous galaxies in the Universe, not to mention star formation, debris disks, asteroids and normal galaxies to z$\sim$ 0.5. The WISE 23μm sensitivity corresponds to detecting the photosphere for G2 ZAMS star at 100 parsecs. Thus WISE will provide a uniform and complete sample of nearby debris disks and YSO targets that will become primary targets for ALMA.

Setting the Stage for Planet Formation: Grain Growth in Circumstellar Disks

Leonardo Testi (INAF-Osservatorio Astrofisico di Arcetri)

Presentation: Wish

In this talk I will review the properties of disks around pre-main sequence stars. I will then discuss the observational evidence for the presence of large grains on the disk midplane, including the possible evidence for radial gradients in the midplane dust properties. The implications of the observations of grain growth for planet formation will be discussed, as well as the directions of future research in this area.

Observations of Disks with the EVLA: What Will it Do for You?

Claire Chandler (NRAO)

Presentation: Invited

The VLA is currently undergoing a dramatic enhancement in sensitivity and capability to become the Expanded Very Large Array (EVLA). Continuous frequency coverage from 1 to 50 GHz and instantaneous bandwidths of up to 8 GHz with up to 4 million spectral channels will provide an extremely powerful tool for studies of disk chemistry, kinematics, and the interaction between disks and jets. While ALMA will clearly revolutionize the study of circumstellar disks, evidence of the growth of dust grains to cm sizes and beyond require measurements of disks at cm-wavelengths. For the youngest, most deeply-embedded protostars, observations at the highest spatial resolution provided by ALMA (at its highest frequencies) will be hampered by optically-thick protostellar envelopes, while the EVLA will be able to peer through the envelope to study forming disks at the earliest phases of evolution. ALMA and EVLA are therefore highly complementary, and I will use recent results from the VLA to highlight future capabilities of the EVLA.

Synergy with Herschel

Brenda Matthews (Herzberg Institute of Astrophysics)

Presentation: Invited

In this talk, we describe the potential for synergy between the ESA Herschel Space Observatory (HSO) and ALMA. HSO is a 3.5-m diameter far-infrared and submillimeter telescope that will be launched next year to the L2 point of the Earth-Sun system. HSO will have three instruments: PACS, SPIRE and HIFI. The first, PACS, is the Photodetector Array Camera and Spectrometer, which will allow simultaneous imaging of continuum emission at 75 or 110 μm and 170 μm over a $1.7'$ x $3.5'$ FOV. The second, SPIRE, is the Spectral and Photo- metric Imaging REceiver, which will allow simultaneous imaging of continuum emission at 250, 360 and 520 μm over a $4'$ x $8'$ FOV. Besides imaging, the PACS and SPIRE instruments also have spectroscopic modes, with PACS offering R = 1500-4000 over a 0.8' FOV over 57-210 μm through a grating and SPIRE offering R = 20-100 over $2.6'$ FOV over 200-670 μm through an FTS. The third HSO instrument, HIFI, is the Heterodyne Instrument for the Far-Infrared, which will allow single-pixel coverage of 157-212 μm and 240-625 μm over $\sim$ 4000 channels with $R = 10^7$. HSO will have a diffraction limited spatial resolution of $\sim$ 15" $* \lambda(\mu\text{m})/250$ μm. HSO is expected to last until 2011, i.e., the year before full operations with ALMA. Given its relatively short operational lifetime, HSO science will be heavily biased toward Key Projects that require $>$ 100 hours of time to address broad scientific questions, although time will remain for shorter, very focused projects. The timing and vast amount of survey data to come from HSO make it an vital pathfinder for high-frequency ALMA observations. For example, disks discovered with PACS or SPIRE will require the high-resolution submillimeter data from ALMA to make progress understanding their internal structure and evolutionary states.

Synergy with JWST

Alycia Weinberger (Carnegie Institution of Washington, Dept. of Terrestrial Magnetism)

Presentation: Invited

The James Webb Space Telescope (JWST) should launch about the time ALMA enters its prime operations period (2013). I will describe the capabilities of the space telescope for high contrast near-infrared imaging of scattered light from disks, compared to current Hubble Space Telescope and ground-based adaptive optics results. Observations of scattered light (60 mas resolution) from JWST will be comparable in spatial resolution to ALMA operating at 450 μm over a 1.5 km baseline. By measuring scattering and emission of dust at the same locations in disks, together these will provide new insights into dust composition. I will also describe JWST's near-infrared spectroscopic and mid-infrared imaging and spectroscopic capabilities. Again, these will complement ALMA's capabilities for dust and gas compositional measurements at longer wavelengths. For example, JWST measurments of molecular hydrogen could be compared to CO abundances from ALMA, both spatially resolved, to understand gas evolution.

Posters

Connecting the Herbig-Haro Object HH 39 with the Disk of Herbig Be star R Mon

Marc Audard (ISDC/Geneva Observatory)

Stephen Skinner (University of Colorado)
Manuel Guedel (Paul Scherrer Institut)
Thierry Lanz (University of Maryland)
Frits Paerels (Columbia University)
Hector Arce (AMNH)

Presentation: Poster

We report on results of our Spitzer Cycle 2 program to observe the young massive star R Mon and the associated HH 39 object in the mid-infrared. The aim of this program is to study the physical links in a young massive star between accretion disk, outflows and jets, and shocks in the associated HH object. Our analysis reveals that several knots of HH 39 are clearly detected in IRAC and at 24 μm, and possibly at 70 μm. The IRS spectra of HH 39 show weak evidence of [Ne II] 12.8 μm and 0-0 S(1) H_2 17.0 μm lines. Finally, we obtained the SH and MIPS SED spectra of R Mon. A PAH emission feature at 11.3 μm is detected on top of the strong continuum. The combined IRAC, IRS, and MIPS data of the R Mon/HH 39 system help us to understand circumstellar disk processing, and the connection between jets, outflows, and HH objects.

Dust Sedimentation in Protoplanetary Disks

Dinshaw Balsara (Univ. of Notre Dame)

David Tilley (Univ. of Notre Dame)

Presentation: Poster

Observations, such as the HST observations of HH30, have provided us with some evidence that the dusty component of a protostellar accretion disk might be settling to the mid-plane of the disk. Other observations of dust to gas ratios along select lines of sight point to a similar conclusion. It is, therefore, very interesting to model such a phenomenon. Without disk turbulence, this process of sedimentation to the midplane takes place extremely rapidly for dust in a range of sizes. It is, therefore, reasonable to conjecture that the turbulence in accretion disks may play some role in giving the dust a large vertical extent. We report on a suite of simulations that probe the development of the magnetorotational instability at a range of radii in a disk that is tuned to have parameters similar to HH30's disk. The sedimentation of dust with a spectrum of sizes in such a self-consistently turbulent accretion disk is studied. We report on the ability of the turbulence to

provide a turbulent diffusivity to the dust and compare dust to gas scale heights as a function of dust size.

Structure of the Nearest Cluster-Forming Dense Core

Tyler Bourke (Harvard-Smithsonian Center for Astrophysics)

Philip Myers (Harvard-Smithsonian Center for Astrophysics)
James Di Francesco (Hezberg Institute of Astrophsics)
Paola Caselli (Harvard-Smithsonian Center for Astrophysics)
David Wilner (Harvard-Smithsonian Center for Astrophysics)
Rene Plume (University of Calgary)

Presentation: Poster

A major problem in astrophysics is how stars form in clusters of ∼100 or more members, in a region extending over ∼1 pc, in a time period of ∼1 Myr, and with a mass distribution following the initial mass function. One of the fundamental questions that needs to be addressed is how do the initial conditions for star formation differ from isolated to clustered cores. Observations at high spectral and spatial resolution are needed, and only interferometers operating at millimeter and submillimeter wavelengths are able to provide the necessary data. The Oph A ridge is the densest gas condensation in the nearest cluster-forming region, where previous observations of the dust continuum emission (30-m) and dense molecular gas traced by N_2H^+ 1-0 emission (30-m + BIMA) with 10″ resolution (1250 AU) have revealed half a dozen local maxima of emission, but only one dust and molecular line peak are coincident. The line widths are narrow and similar to those observed from isolated dense cores, but the resolution is insufficient to reveal the structure of individual cores.

With the SMA we have observed the Oph A ridge in the dust continuum at 1.3 mm and in the quiescent molecular gas in the 3-2 line of N_2D^+ with a resolution of $\sim 3''$. Toward the core with the narrowest N_2H^+ linewidth, N6, additional very high spectral resolution observations (0.06 km/s) were made, and the data combined with JCMT observations to recover the emission on all spatial scales. All of the N_2H^+ cores are detected in N_2D^+, and weak compact continuum emission is also coincident with each molecular line maxima, which was not the case for the single dish continuum emission. This may be a temperature effect, where the weak emission from the cold dust associated with each core is undetectable against the bright background from the warm dust in the ridge in the single-dish observations. This result suggests that while the Oph A ridge resembles an elogated isolated core in its density structure in single dish maps, but with a larger peak density, when observed with an interferometer with higher spatial resolution it breaks up into smaller clumps of mass < 0.1 $M_\odot$, suggesting fragmentation into smaller units than a typical isolated core. The observations of N6 reveal velocity structure with increasing line-widths toward the core's dust continuum peak, which may be a sign of increasing turbulence or inward motions toward its center. Analysis of the data is in progress and the results will be discussed during this presentation.

Through Disks to Stars and Planets: from eSMA to ALMA

Sandrine Bottinelli (Leiden Observatory)

Richard Chamberlin (CSO)
Remo Tilanus (JCMT)
Ken Young (SAO/CfA)
Huib Jan van Langevelde (Leiden Observatory / JIVE)
Ewine van Dishoeck (Leiden Observatory)
Michiel Hogerheijde (Leiden Observatory)
eSMA commissioning team (SMA/JCMT/CSO)

Presentation: Poster

The eSMA, which brings together the SMA, JCMT and CSO, will be an important facility to prepare the grounds for ALMA. The increased baselines and collecting area will bring new insights in a variety of fields, in particular in the study of disks. We will present the characteristics of the eSMA as well as the results of the on-going commissioning.

Combined Array for Research in Millimeter-wave Astronomy (CARMA)

John Carpenter (Caltech)

Douglas Bock (CARMA)
the CARMA Team

Presentation: Poster

The Combined Array for Research in Millimeter-wave Astronomy (CARMA) has been formed from the millimeter-wave antennas of the Owens Valley Radio Observatory (OVRO) and the Berkeley-Illinois-Maryland Association (BIMA) Array. CARMA consists of six 10.4-m and nine 6.1-m diameter antennas on a site at elevation 2200 m in the Inyo Mountains near Bishop, California. The array is operated by an association that includes the California Institute of Technology

and the Universities of California (Berkeley), Illinois (Urbana-Champaign), and Maryland. The University of Chicago's Sunyaev-Zel'dovich Array (SZA) is expected to join CARMA with eight 3.5-m antennas in 2008. CARMA has been conducting community 3 mm observations since the beginning of 2007 in two of the five antenna configurations. Commissioning observations at 1 mm are underway, and antenna configurations containing very short (8 m) and long (1.7 km) baselines will be commissioned later this year. The next call for proposals will be issued this summer.

Probing the Evolutionary Stage of Twin Molecular Envelopes Associated with the L723 Class 0 Protostar

Josep Miquel Girart (Institut de Ciencies de l Espai (CSIC-IEEC))

Estalella, Robert (Universitat de Barcelona)
Ramprasad Rao (Submillimeter Array)

Presentation: Poster

We present SMA observation of the dust and molecular line emission toward L723, a low luminosity Class 0 protostar. We found that the dust emission is resolved in two twin cores (similar size and flux) separated by $3'$ (900 AU). We have carried out an analysis of the molecular line and dust emission and of the properties of theses two cores at different frequencies. We found that these two apparently twin cores are in different evolutionary stages, both from the chemical and dynamical point of view. One of them has associated one or two outflow and it may harbor protostellar system. The other core shows no clear signs of outflow activity and it could be in the earliest stage of the collapse phase.

Observing Extrasolar Planetary Systems with ALMA

Antonio Hales (NRAO)

Rob Reid (NRAO)

Presentation: Poster

In this poster we will address the ability of ALMA to observe extrasolar planetary systems (in various stages of formation). The observation of extrasolar planetary systems is thought to be

one of the most important science drivers for ALMA. As such, we provide some idea of what the capabilities might be in this regard.

Herbig Stars Disks: Probing the Properties of HD 163296 Disk and PV Cep Circumstellar Structure

Murad Hamidouche (Univ. of Illinois)

Leslie Looney (Univ. of Illinois)
Lee Mundy (Univ. of Maryland)

Presentation: Poster

We present Very Large Array observations of dust emission at $\lambda = 7$ mm around two Herbig stars HD 163296 and PV Cep. We have detected a disk-like structure around PV Cep of a radius $\sim$ 600 AU and a P.A. = 15^o. We probe the detected PV Cep circumstellar structure by fitting a disk model. We have also resolved the disk around HD 163296 of a radius $\simeq$ 200 AU and a P.A. = -22^o. We probe the dust properties in these disks and compare their evolutionary stages. This is the first time where the disk around HD 163296 were resolved at this wavelength.

An Inner Hole in the Disk of TW Hya Resolved in 7mm Dust Emission

Meredith Hughes (Harvard-Smithsonian CfA)

David Wilner (CfA)

Presentation: Poster

We present 7mm VLA observations of the disk around TW Hya (distance 51 pc) that resolve dust emission at 4 AU scales and reveal the inner hole in the nearly face-on disk, a feature predicted from spectral energy distribution modeling. The data indicate a bright ring structure, which we associate with the frontally illuminated inner edge of the truncated outer disk. This system is an ideal target for detailed study of the transition between gas-rich disks around young T Tauri stars and the tenuous debris disks which follow in the planet formation process. The observed clearing of the inner disk plausibly results from the dynamical effects of a giant planet in formation. Future

studies with ALMA will place constraints on the structure of this critical region and potentially reveal features associated with the protoplanet. We also describe a simple analytical framework to aid in the interpretation of visibility functions from the central regions of transition disks with an inner hole and surrounding bright wall.

Millimeter Imaging of HD163296: Probing the Disk Structure and Kinematics

Andrea Isella (INAF-Osservatorio Astrofisico di Arcetri, Italy)

Presentation: Poster

Millimeter and sub-millimeter interferometers are providing an increasingly detailed description of disks around pre-main sequence stars of solar and intermediate mass. In this talk I will present new multi-wavelength interferometric observations of the Herbig Ae star HD 163296 (5 Myr) obtained with the VLA, SMA and Plateau de Bure array both in the continuum (1.3, 2.8, 7 mm) and in the ^{12}CO and ^{13}CO emission lines. Gas and dust properties have been obtained comparing the observations with a self-consistent model for the continuum and the CO emission. We find a strong evidence that the disk is in keplerian rotation around a star of 2.6 $M_{\odot}$ and constrain its orientation in the sky. We confirm the presence of mm/cm-size grains in the disk mid plane. We show that the dust emission is asymmetric and confined inside a radius of 200 AU, while the CO emission extends up to 540 AU. The comparison between the CO and dust temperature implies also that the CO is photodissociated in the disk atmosphere. All this results support the idea that the disk around HD 163296 is strongly evolved, harboring the formation of planet-size bodies in its outer regions.

Molecular Observations Towards Bipolar Outflows of L1448

Woojin Kwon (University of Illinois at Urbana-Champaign)

Leslie W. Looney (University of Illinois at Urbana-Champaign)

Presentation: Poster

The youngest Young Stellar Objects (YSOs) are characterized by well developed bipolar outflows, which also imply the existence of circumstellar disks, and massive, optically thick envelopes.

Multiple bipolar outflows have been revealed in the L1448 dark cloud. In addition, polarimetric observations have been carried out in the the L1448 IRS 3 region, which illustrate magnetic fields in the driving source as perpendicular to the bipolar outflow (Kwon et al. 2006). Recently it Spitzer Space Telescope images using the it Infrared Array Camera (IRAC) have also shown the outflow cavities in scattered light. We are conducting further molecular observations such as CO, ^{13}CO, $C^{18}O$, CS, SiO, HCO^+, and N_2H^+ toward two regions of L1448 (L1448 IRS 2 and IRS 3), in order to address the driving mechanism of bipolar outflows as well as the physical and chemical properties of the outflows and envelopes, using the recently commissioned Combined Array for Research in Mm-wave Astronomy (CARMA) with high sensitivity, high image fidelity, and high angular and spectral resolution. The current results of the observations, compared to the Spitzer IRAC images, are presented.

The Extremely High-Velocity Molecular Outflow in IRAS 20126+4104

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Presentation: Poster

Sensitive CO(2-1) observations of the massive star-forming region IRAS 20126+4104 reveal a high-velocity gas component that has not been observed before. Comparing the morphologies of the high-velocity CO and the molecular jet traced by H_2 and SiO, we found various orientations projected on the plane of the sky that could be interpreted in terms of jet precession. The outflow shows a steepening mass spectrum with increasing flow velocities. The high-velocity gas in IRAS 20126+4104 contributes significantly to the energy and momentum of the flow.

The Space Infrared Interferometric Telescope (SPIRIT) and its Complementarity to ALMA

David Leisawitz (NASA Goddard Space Flight Center)

SPIRIT Mission Study Team ()

Presentation: Poster

We report results of a pre-Formulation Phase study of SPIRIT, a candidate NASA Origins Probe mission. SPIRIT is a spatial and spectral interferometer with an operating wavelength range 25 - 400 μm. SPIRIT will provide sub-arcsecond resolution images and spectra with resolution $\lambda/\Delta\lambda = 3000$ in a 1 arcmin field of view to accomplish three primary scientific objectives: (1) Learn how planetary systems form from protostellar disks, and how they acquire their variable composition; (2) Characterize the family of extrasolar planetary systems by imaging the structure in debris disks to understand how and where planets of different types form; and (3) Learn how high-redshift galaxies formed and merged to form the present-day population of galaxies. In each of these science domains, SPIRIT will yield information complementary to that obtainable with the James Webb Space Telescope (JWST) and the Atacama Large Millimeter Array (ALMA), and all three observatories could operate contemporaneously. Here we shall emphasize the SPIRIT science goals (1) and (2) and the mission's complementarity with ALMA.

Probing the Dynamical Evolution of Orion Source I on 10-100 AU Scales: Results from the KaLYPSO Project

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Presentation: Poster

A comprehensive picture of high-mass star formation has remained elusive, in part because examples of high-mass YSOs tend to be relatively distant, deeply embedded, and confused with other emission sources. These factors have impeded dynamical investigations within tens of AU of high-mass YSOs—scales that are critical for probing the interfaces where outflows from accretion disks are launched and collimated. Using VLA and VLBA observations of H_2O and SiO masers, the KaLYPSO project (http://www.cfa.harvard.edu/kalypso/) is overcoming these limitations by mapping the structure and dynamical/temporal evolution of the material 10-1000 AU from the nearest high-mass YSO: Radio Source I in the Orion BN/KL region. Our data include multiple ($\sim$40) epochs of VLBA observations over a several-year period, allowing us to track the proper motions of individual SiO maser spots and to monitor changes in the physical conditions of the emitting material with time. Ultimately these data will provide 3-D maps of the outflow structure over approximately 30% of the outflow crossing time. These maps in turn will supply unprecedented new constraints on the mechanisms (e.g., magnetic fields) that are shaping the evolution of this high-mass YSO. I will summarize recent results from the KaLYPSO project, including compelling evidence that high-mass star formation is occurring via disk-mediated accretion. I will then discuss how the frequencies and spatial scales accessible with ALMA will provide provide complementary insight into the process of high-mass star formation in Orion and other high-mass star-forming regions.

Molecular Gas and Dust Content of the Disk around HD169142

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Presentation: Poster

Gas-phase molecular line emission probes the internal structure, chemical composition and kinematics of protoplanetary disks. We present observations of ^{13}CO and C^{18}O J=2–1 lines from the disk around the Herbig Ae/Be star HD169142 at 1.4″ resolution (D=145 pc) obtained with the Submillimeter Array as well as some new analysis of the previously published 1.3mm continuum (Raman et al. 2006). The ^{13}CO and C^{18}O emission shows a resolved disk ($R \sim$ 230AU) in Keplerian rotation. Using the same model that fits well the ^{12}CO data, we analyse the ^{13}CO and C^{18}O lines and the continuum using the molecular excitation and radiative transfer code of [1]. We draw conclusions about the amount of the gas in the disk, gas to dust ratio, disk outer radius and properties of the regions where the emission arises.

Radial Dependence of Dust Composition in T Tauri Disks from Spitzer IRS Spectra

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Presentation: Poster

The 5-36 μm spectra of 70 T Tauri stars in the Taurus/Auriga star-forming region obtained with the Infrared Spectrograph (IRS) on board the Spitzer Space Telescope are analyzed. We construct models consisting of optically thin dust and blackbodies at two temperatures (typically, 400 K and 170 K, roughly corresponding to distances of 0.6 AU and 5 AU, respectively, from center of disk) to fit each object's spectrum. The optically thin emission in each model corresponds to emission from the disk atmosphere, while the blackbodies in each model represent emission from disk midplane and from optically thin dust with featureless emissivity such as amorphous carbon; the components at the higher temperature correspond to emission from the inner disk, while those at the lower temperature correspond to emission from the outer disk. These models use opacities of laboratory analogs of cosmic dust, such as subμm nonspherical grains of amorphous silicates, crystalline silicates (forsterite and pyroxene), and silica, and also large porous silicate grains. A wide range in the fraction of crystalline silicate grains and large silicate grains in inner and outer disks amongst these 1-3 Myr old stars is found. The dust in the remnant outer disks of the transitional-disk objects CoKu Tau/4, GM Aur, and DM Tau has the simplest form of silicates, with almost no hint of crystalline components and modest amounts of large grains. The 10 μm wavelength silicate emission features of these transitional-disk objects are very similar to that of the mass-losing supergiant Mu Ceph and also to the 10 μm wavelength ISM absorption feature measured along the line-of-sight to the Galactic Center. This indicates that the dust grains in the transitional-disk objects have been modified little from their origin in the interstellar medium. However, nearly all of the non-transitional disks (those whose inner disks have not been cleared of dust) show signs of at least some dust processing and grain growth. The relations of the mass fractions of the various dust components to stellar and disk parameters, such as the mid-infrared spectral energy distribution colors presented by Furlan et al. (2006) and submillimeter continuum slopes, as well as to the mass fractions of other dust components (inner and outer disk) are explored. By comparing mid-infrared evidence for subμm-to-μm grain growth to submillimeter wavelength studies of protoplanetary disks, we explore implications for studies of dust grain growth in these disks using ALMA.

High-Energy and Dynamic Chemistry in Protoplanetary Disks and Predictions for ALMA

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Presentation: Poster

Protoplanetary disks discovered around a number of young stars are believed to be the cradles where planets born. The study of their physics and chemistry is of particular importance if initial conditions and general trends of planet formation are to be understood. In recent years a significant progress in our understanding of their basic physical and chemical structure was achieved. However, their active dynamical nature and its influence on the disk chemical structure have not yet been fully addressed. In my presentation, I will describe new interesting results concerning various aspects of the disk chemistry and physics which were obtained at the Plateau de Bure interferometer, IRAM 30-m antenna, and Submillimiter Array within the "Chemistry in Disks" (CID) collaboration (Heidelberg, Bordeaux, Jena, Grenoble, Paris). A particular emphasis will be placed on theoretical interpretation of the multi-line, multi-molecule interferometric observations of the T Tau and Herbig Ae disks. In essence, the following topics will be discussed: 1) a link between grain properties, high-energy stellar radiation, and disk ionization structure; 2) a link between turbulent mixing and gas-grain chemistry in dynamically active disks; 3) chemical disk structure as seen with the ALMA interferometer.

Angular Momentum Transport in Protostellar Disks

Jake Simon (UVa)

John Hawley (UVa)
Kris Beckwith (UVa)

Presentation: Poster

It is now known that a subthermal magnetic field coupled to differentially rotating gas in an accretion disk produces turbulence through the magnetorotational instability (MRI). This turbulence drives outward angular momentum transport at an enhanced rate. Recent studies have shown that non-ideal effects, such as nonzero resistivity and viscosity, are important in determining the level of this transport (Fromang & Papaloizou 2007, Fromang et al. 2007, Lesur & Longaretti 2007). Analyses of the MRI in the context of protostellar disks, where these non-ideal effects are more relevant, have not been carried out in sufficient detail. We present a study of the MRI with the magnetohydrodynamics code ATHENA by simulating a local region in an accretion disk. Without physical resistivity and viscosity, ATHENA accounts for these dissipation terms through numerical dissipation. We show that this numerical dissipation can mimic physical dissipation by considering the evolution of the gas energy in its various forms. However, to examine the nature of non-ideal effects, more realistic dissipation is needed.

Structure and Evolution of Outflows

Thangasamy Velusamy (JPL)

William D. Langer (JPL)
Kenneth A. Marsh (JPL)

Presentation: Poster

Circumstellar outflow is believed to play a central role in the dispersal of the envelope and the ejection of angular momentum from protostars and their associated disks . To study the time evolution of the outflow and its effects on infall and accretion, we need to compare the outflow characteristics of each object with key physical parameters of the protostar, protostellar disk, and the envelope. We present examples of outflow cavities imaged by Spitzer in scattered light in IRAC bands in a large sample of 142 outflows. For all the outflows in this sample we use the MIPS 24 and 70 μm excess as a proxy for the protostellar disk and envelope that is used in modeling the outflow cavities. Our sample provides a uniform data set processed using a set of unique analytical tools, HiRes (achieving sub-arcsec, $\sim 0.8''$ at 3.6 and 4.5 μm) and the Outflow Cavity Model. The primary output of these models is a robust set of opening angles which are correlated with such inferable parameters as age, envelope mass, and disk geometry to provide information on how the outflow is shaped and how it evolves. However presently available observations ($0.5''$-$1''$) do not probe the outflows deep down to their launch site and they only provide data on the larger scale properties of the outflow. Our outflow sample will provide ALMA with a set of objects to study with its high resolution ($< 0.1''$) and enable it to probe the structure and kinematics of the outflow cones closer to their launch site from disk/disk-stellar magnetosphere interaction and their time evolution.

The Growth of Protostellar Discs

Derek Ward-Thompson (Cardiff University)

Presentation: Poster

We compare interferometry observations with single-dish observations at sub-millimetre wavelengths. The interferometer data trace circumstellar discs around young stellar objects. As an example we show data for the Class I proto-star L1709B and show that it has a disc that can be modelled with a gaussian of roughly 60AU (FWHM). We compare this with other data from the literature and we make the comparison between the flux seen by the single-dish observations, which trace the envelope mass, and the flux recovered by the interferometer observations, which trace the disc mass. We compare this ratio with the evolutionary status of the proto-star, as measured by its bolometric temperature. We find that the ratio of the disc to envelope mass increases with evolutionary status.

Multi-Epoch VLBI Observations of the Water Masers Associated with NGC1333/IRAS4A and IRAS4B

Al Wootten (NRAO)

Mark Claussen (NRAO)
Kevin Marvel (AAS)
Bruce A. Wilking (UMSL)

Presentation: Poster

We present results of multi-epoch VLBI observations of the water masers associated with IRAS 4A and IRAS 4B in the NGC 1333 star-forming region. Both objects have been classified as Class 0 sources and each source is known to be a multiple system. With the Very Long Baseline Array, we detected 35 masers in Epoch I, 40 masers in Epoch II, 35 in Epoch III, and 24 in Epoch IV. These data are used to calculate proper motions for the masers and trace the jet outflows within 100 AU of IRAS 4A2 and IRAS 4BW. In each source, the water masers are found in two regions, one blue-shifted with respect to the systemic velocity and the other red-shifted. In IRAS 4A, the blue-shifted masers are to the NW and in IRAS 4B, the blue-shifted masers are to the SE. In IRAS 4B, the masers form complex, but roughly linear structures with a thickness of 3 mas (1 AU). The masers are expanding linearly away from each other at velocities of 53 km s^{-1} (IRAS 4A) and 78 km s^{-1} (IRAS 4B). The relationship of the masers to larger scale outflows is discussed.

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