1. Solar System


C. Z. Cheng and Y. H. Yang (Plasma and Space Science Center, National Cheng Kung University, Tainan, Taiwan)

Solar flares and coronal mass ejections are the most powerful energy release process in the solar system. They have been observed by using soft and hard X-rays, EUV, visible light, sub millimeter, millimeter and microwaves. I will present observations of flares and associated coronal mass ejections and the theory of magnetic reconnection to explain the observed results.

1.2. Estimation of Reconnection Electric Field in Two-Ribbon Flares

Y.-H. Yang and C. Z. Cheng (Plasma and Space Science Center, Nation Cheng Kung University; Institute of Space, Astrophysical and Plasma Sciences, Nation Cheng Kung University; Department of Physics, Nation Cheng Kung University)

The magnetic reconnection in the corona is generally believed to be responsible for the energy release and particle acceleration in solar flares. After electrons are accelerated from the reconnection site (at SXR looptop), the electrons will emit gyrosynchrotron radiation in the millimeter and sub-millimeter range as they travel along the magnetic field downward to hit the chromosphere. Thus, from the millimeter and sub-millimeter observations, we should be able to determine the particle acceleration mechanism. In this study, the separations of two ribbons observed by Ha/EUV, as well as the HXR footpoint motions observed by RHESSI, are used as the chromospheric signatures of progressive reconnection. To determine the reconnection electric fields in a flare, we estimate the magnetic flux change rate in the areas of enhanced Ha/EUV intensity and HXR kernels at a flaring time. The spatial and temporal relationship between the reconnection electric fields and the HXR intensity will be addressed and discussed here.

2. Galactic Star Formation: Low-Mass

2.1. The Submillimeter Polarization Spectrum of the DR21/DR21(OH) Molecular Cloud

T.-C. Ching and S.-P. Lai (National Tsing Hua University, Hsinchu, Taiwan)

We present the first comparison of thermal dust polarization emission at 350 µm and 850 µm in the DR21/DR21(OH) molecular cloud. The data were taken using the Caltech Submillimeter Observatory (CSO) at 350 µm wavelength and the James Clerk Maxwell Telescope (JCMT) at 850 µm wavelength. The ratio of 850 µm to 350 µm polarization is 1.6 ± 0.7 in the envelope of the DR21(OH) molecular cloud and drops about 40% toward its core, while in the DR21 molecular cloud the ratio is 1.2 ± 0.4 in the envelope and only slightly increases toward the DR21 core. With a simple two temperature model, we derive the first order difference of the magnetic fields between two layers of dust grains.

2.2. Ammonia and CCS as diagnostic tools of low-mass protostars


The spatial distribution from various molecules...
lar species depend not only on the physical conditions within the molecular clouds, but also on the time-dependent chemistry. That is the case of CCS (early-type molecule) and ammonia (late-type molecule), which can be used as a kind of "clock" to date the age of dense cores. In this talk we present a sensitive and systematic single-dish survey in ammonia and CCS at 1 cm, towards a sample of low-mass young stellar objects known to harbor water maser emission. We have used the properties of these molecules as tools for obtaining information about the physical conditions and stage of the evolution of low-mass young stellar objects. Our main purposes were to search for the youngest protostars and to find the best candidates to perform interferometric observations, in order to study at higher resolution the structure, kinematics and physical properties of very young star-forming regions. As a follow up to our survey, we show interferometric observations in CCS, ammonia and water masers using the Very Large Array (VLA) towards the young protostars B1-IRS, L1448-IRS3, and L1448C. Our results suggest that CCS abundance could be enhanced via shock-induced chemistry. In addition, we have observed a spatial anticorrelation between CCS and ammonia at scales of $\sim 5''$, and it illustrates the importance of time-dependent chemistry studies on small spatial scales. Some of our CCS maps have been produced by applying for the first time the cross-calibration technique for molecular spectral lines.

2.3. Fitting magnetized molecular cloud collapse models to NGC 1333 IRAS 4A

P. Frau-Méndez (Institut de Ciències de l’Espai (CSIC-IEEC), Barcelona, Catalunya, Spain), J.M. Girart (Institut de Ciències de l’Espai (CSIC-IEEC), Barcelona, Catalunya, Spain), D. Galli (Osservatorio Astrofisico di Arcetri (INAF), Firenze, Italy)

Magnetic fields are believed to play an important role in the star formation process. Grain alignment is one of the visible effects of the magnetic fields polarizing the dust emission perpendicularly to the field lines. To test the influence of magnetic fields we compare high-angular resolution observations of the submillimeter polarized emission of the low-mass proto-star NGC 1333 IRAS 4A with collapse models of magnetized molecular cloud cores. We assume a model density and magnetic flux function to compute the Stokes parameters and synthetic polarization maps convolved with the interferometric response. Our synthetic maps show a magnetic field morphology in a good agreement with the data suggesting that this theoretical scenario is a plausible explanation. Consequently, instead of turbulence, well-ordered magnetic fields control the evolution of low-mass star-forming molecular cloud cores.

2.4. Early stages of clustered star formation in the outer Galaxy

W.F. Frieswijk and R. F. Shipman (Kapteyn Astronomical Institute, Groningen, The Netherlands)

TBA

2.5. Physical and Chemical Studies of Low-Mass Star Forming Region: the Pipe Nebula

Kei Fukue, Yoshito Shimajiri, Takashi Tsukagoshi, and Yasutaka Kurono (University of Tokyo), Masao Saito (NAOJ), Fumitaka Nakamura (Niigata University), Aya Higuchi (Tokyo Institute Technology), Masaaki Hiramatsu (ASIAA), Norio Ikeda (JAXA), and Ryoeji Kawabe (NRO), AzTEC team and NRO 45m Legacy team

We have carried out molecular line and continuum observations of the Pipe Nebula, a low-mass star forming region at a distance of 130 pc, to obtain the initial conditions of star formation at a low-mass star forming region. Star formation in the Pipe Nebula is active only in the western edge of the nebula B59. First, we observed the nebula in 1.1 mm continuum with the AzTEC/ASTE. We obtained three continuum maps ($\sim 35''\times35''$) at Core1-2, Core3, and Core9-11 regions identified by Onishi et al. (1999) in $^{13}$CO. We resolved some cores detected in the previous extinction map, and found 64 cores in total, which is more than twice the number of extinction cores located in our observed areas. Next, we performed a multi line survey at $^{13}$CO(1–0), HC$_3$N(12–11,9–8), CCS(7,6–6,5), N$_2$H$^+$ (1–0), and SO(2(3)–1(2))
with the Nobeyama 45m telescope. We use C$^{18}$O, which can trace the high density gas, to estimate the velocity widths of the cores. Other molecular lines are used to deduce the evolutionary stages of the cores. Our observations showed that a velocity width of C$^{18}$O is 0.7 km/s in Core1 appropriate to B59, 0.5 km/s in Core9-11, and is narrow (~0.35 km/s) in the other regions. A similar trend was found in the other molecular line observations. The detection rates of N$_2$H$^+$, tracing late evolutionary stages, toward to the cores are 45% at Core1(B59) and 32% at the other regions. Hence, we find out that the physical states and the evolutionary stages are obviously different in B59 and the other regions. Thus, since the C$^{18}$O velocity width does not monotonically increase along the nebula, we do not consider that the star formation activity simply propagates from B59 to the south.

2.6. Study of Outflow in a VeLLO, L328-IRS

Chang Won Lee, Gwangeong Kim and Mi-Ryang Kim

The Very Low Luminosity Objects discovered in molecular cores and clouds by c2d Legacy project are important targets to study because their properties are similar to those of protostars but hard to understand their faintness in the context of present standard star formation theory. A new VeLLO recently discovered, L328-IRS, also has properties of a protostar, but is the faintest among the VeLLOs and expected to grow to a brown dwarf regarding that the mass of its surrounding envelope is too small (of order 0.1 solar mass) as a provider of material for L328-IRS. Study on the outflow activity in L328-IRS may be the best way to find the origin of its faintness and its fate. However, the outflow activity in the VeLLO is usually hard to detect and study properly because of its weakness. Nevertheless we found several observational hints of the existence of the outflow from L328-IRS in NIR and recent molecular line observations which will be discussed in the poster.

2.7. Millimeter- and Submillimeter-Wave Observations of Barnard 1-bN and Barnard 1-bS

Fang-Chun Liu (Academia Sinica Institute of Astronomy and Astrophysics, Taipei, Taiwan and Graduate Institute of Astronomy, National Central University, Taoyuan County, Taiwan), Naomi Hirano (Academia Sinica Institute of Astronomy and Astrophysics, Taipei, Taiwan), Shih-Ping Lai (Physics Department and Institute of Astronomy, National Tsing Hua University, Taiwan), Tomofumi Umemoto (National Astronomical Observatory of Japan, Japan)

The physical and chemical properties of two mm/sub-mm sources in Barnard cloud, Barnard 1-bN and Barnard 1-bS, are studied with multi-wavelength observations. The dust continuum from these two sources shows spacially compact distribution and very cold spectral energy distributions (T$_{dust}$=11-16 K). These two sources have no mid-IR counterpart in the Spitzer MIPS 24 and 60 micron bands, indicating that they are deeply embedded. The CO J=2-1 data obtained with the SMA suggest that B1-bS and probably B1-bN are associated with the compact (~2000 AU size) molecular outflows. These results propose that Barnard 1-bN and Barnard 1-bS are already harboring Class 0 protostars. On the other hand, the chemical properties of these two sources are similar to those of pre-stellar cores: the N$_2$D$^+$ J=3-2 emission is strongly detected (0.3 K for B1-bN and 0.1 K for B1-bS) and clearly traces the two compact sources, while the H$^{13}$CO$^+$ J=1-0 emission is weak or barely detected near or at the continuum peaks. This lack of H$^{13}$CO$^+$ emission is probably due to the depletion of the H$^{13}$CO$^+$ molecule onto the grain under the condition of low temperature and high density, as in the case of pre-stellar cores. The observed physical and chemical properties suggest that B1-bN and B1-bS are in the very beginning stage of protostellar evolution, probably in the evolutionary stage between pre-stellar core and class 0 source.

2.8. Modeling the continuum emission of the supersonically contracting star-forming core ahead of HH 80N

J.M. Masqué and R. Estalella (Departament
2.10. Dense Cores in the ρ Ophiuchi Main Cloud: External Pressures and Small Scale Turbulent Driving in Clustered Star Formation

F. Nakamura, H. Maruta, R. Nishi, N. Ikeda, and Y. Kitamura (1Niigata University, 2ISAS/JAXA)

Using the archive data of the H$^{13}$CO$^+$ ($J = 1 \rightarrow 0$) molecular line emission taken with the Nobeyama 45m radio telescope (beam size: 18$'' \approx 0.01$pc), we identified 68 dense cores in the central dense region of the ρ Ophiuchi main cloud. The mean radius, FWHM velocity width, and LTE mass of the identified cores are estimated to be 0.045 pc, 0.49 km s$^{-1}$, and 3.4 $M_\odot$, respectively.

The majority of the identified cores have subsonic internal motions. From the comparison with the 850μm dust continuum map, we found that the fractional abundance of H$^{13}$CO$^+$ approximately follows the relation $X_{H^{13}CO^+} \propto N_{H_2}^{-1/2}$ with a mean of 1.72 × 10$^{-11}$, where $N_{H_2}$ is the H$_2$ column density. The detailed virial analysis indicates that the surface pressures often dominate over the self-gravity and thus play a crucial role in regulating core formation and evolution. Physical properties of our cores are compared with those of the H$^{13}$CO$^+$ cores in the Orion A molecular cloud recently observed with the same telescope. We found that statistical properties of physical quantities are similar for both core samples if the effect of different spatial resolutions is corrected. The velocity widths of dense gas in the ρ Ophiuchi main cloud appear to be more or less flat over the range of 0.01 – 0.1 pc and have significant excess from the Heyer & Brunt velocity width-size relation. This excess may be evidence of the small scale turbulent driving (e.g., protostellar outflows and gravitational motions) in the cluster environment.
Using the polarimetry system on the Submillimeter Array, we have been able to obtain high resolution (about 1 arc second) maps of polarized dust emission from regions of active star formation. A growing number of researchers have used this system successfully to obtain results that could not have been obtained before. The primary advantages of observing at submillimeter wavelengths is that the dust emission is quite strong and the polarization produced can usually give us the direction of the magnetic field without any ambiguity. In this poster, the results of such an observation that was conducted towards the young star forming region IRAS 16293 are presented. In this binary system the magnetic field structure is substantially different in the two components. This observation, in conjunction with other related measurements such as kinematics and chemical differentiation, appears to indicate that the two protostellar condensations are likely in different stages in their evolution.

2.12. An ASTE Survey of 330-350 GHz lines toward Class 0 Protostars

H. Takami, N. Hirano, S. Takakuwa, M. Hirramatsu, J. Karr, C.-F. Lee (Academia Sinica Institute of Astronomy and Astrophysics, Taipei, Taiwan), M. Momose (Ibaraki University, Mito, Japan), and Kunihiko Tanaka (Institute of Astronomy and Astrophysics, Taipei, Taiwan), S. Kim (Sejong University, Seoul, South Korea), and A. Muench (Harvard-Smithsonian Center for Astrophysics, Cambridge, MA, USA)

We have made survey observations of 25 Class-0 protostars using the ASTE 10-m telescope, Chile. Our spectra cover CO J=3-2 (345.8 GHz), SiO J=8-7 (347.3 GHz), SO J=8_J–8_J (346.5 GHz), SO2 J=16_J–16_J (346.7 GHz) and CH3OH-A J=16_J–16_J (345.9 GHz) with a detection limit of ~0.1 K. Seven protostars show high-velocity peaks in CO emission in addition to wing emission, and/or SiO emission blue/red-shifted from the cloud velocity. These are presumably associated with collimated molecular flows. SO, SO2, SiO and CH3OH emission at the cloud velocity were observed toward 9, 5, 4 and 2 protostars respectively, and mapping observations toward two of them indicate that these emissions originate from a compact region at <30'' from the protostar. Among these protostars, two are associated with both signatures of high-velocity peaks and SO/SO2/SiO/CH3OH emission at the cloud velocity. The remaining 12 targets do not show either signature. Together with Spitzer archival data, we will investigate (1) correlation of the presence/absence of collimated molecular flows with protostellar mass and their evolutionary stages; and (2) the physics and chemistry which allow quiescent SO/SO2/SiO/CH3OH emission at 330–350 GHz to be observed. This study will let us identify protostars for follow-up observations using SMA and ALMA to understand the early stages of protostellar evolution in the general case in further detail.

2.13. Millimeter compact sources within the OMC1 filaments

P.S. Teixeira (European Organisation for Astronomical Research in the Southern Hemisphere, Garching bei Munchen, Germany), L.A. Zapata (Max-Planck-Institut für Radioastronomie, Bonn, Germany), P. Ho and S. Takahashi (Academia Sinica Institute of Astronomy and Astrophysics, Taipei, Taiwan), S. Kim (Sejong University, Seoul, South Korea), and A. Muench (Harvard-Smithsonian Center for Astrophysics, Cambridge, MA, USA)

We report Submillimeter Array (SMA) 1.3 mm observations of the the OMC1 northern filaments that were previously identified from SCUBA JCMT 850 micron continuum and VLA ammonia observations. We find 16 compact sources along an extent of 3' within the filaments. The sources range in mass from 0.8 to 2.8 M☉ and 3 of them are driving highly collimated CO molecular outflows. The millimeter emission may be arising from the circumstellar disk and inner part of the envelope; these compact sources are therefore in the Class 0/I evolutionary phase. We find tentative indications of a mass gradient along the filaments: the more massive sources are located in the southern end whereas the least massive protostars are in the northern end. Finally, the spatial analysis of the protostars shows that these are separated by a quasi-equidistant length of 30'' (0.06 pc), consistent with the Jeans length (for a temperature of 17 K and a mean density of 1.9×10^3 cm^-3), i.e., thermal fragmentation. The star formation within these filaments may therefore be similar to
that of the Spokes cluster in NGC 2264, although observed at a much earlier phase!

2.14. Molecular Observations in BHR 71

T. Britton and M. Voronkov (Australia Telescope National Facility, Sydney, Australia)

BHR 71 is a low mass star-forming region that contains two proto-stellar objects each with an associated outflow. We observed BHR 71 using on-the-fly mapping with the Mopra single dish, located in Siding Spring, Australia. 12 zooms at 33.39 GHz, and 16 zooms at 41.49 GHz were used. We report the first detections of the methanol transitions at 36.1 GHz and 48.3 GHz, HC3N at 36.4 GHz and 45.5 GHz, CS at 48.7 GHz, and SiO at 43.4 GHz for this source.

Methanol at the 36.1 GHz transition can be either thermal or a maser. We obtained 6 hours green time on the Australia Telescope Compact Array located in Narribri, Australia in order to observe this transition, using 1024 channels and 4 MHz bandwidth.

We report that this transition is not an obvious maser as there were no detections on the longer baselines of an EW352 configuration. We obtained a brightness temperature of 34.35 K for the northern lobe and 13.84 K for the southern lobe of the molecular outflow. This is the first observation of a possible maser in a low mass star forming region with an interferometer.

2.15. Precessing Outflow in the L1551 IRS5 Protostellar System

Po-Feng Wu, Shigehisa Takakuwa, Jeremy Lim (Academia Sinica Institute of Astronomy and Astrophysics, Taipei, Taiwan)

The multiple protostellar system L1551 IRS5 exhibits a large-scale bipolar molecular outflow that spans 1.5 pc on both NE (redshifted) and SW (blueshifted) sides of the system. We have studied this outflow within 4000 AU of its central protostars in CO(2→1) at a resolution of 4(560) with the SubMillimeter Array. Our image reveals three distinct molecular outflow components. 1) An X-shaped structure, with a similar symmetry axis and velocity pattern as the large-scale outflow, extending 20" (3000 AU) from center. This structure comprises the limb-brightened walls of a cone-shaped cavity excavated by one or both outflows from the two main protostellar components. 2) A compact central component, also with a similar symmetry axis and velocity pattern as the large-scale outflow, spanning only 1.4" (200 AU) from center. This component likely comprises material within the cavity newly entrained by one or both outflows from the two main protostellar components. 3) A previously unknown S-shaped structure, with an opposite velocity pattern but approximately the same symmetry axis as the large-scale outflow, extending 10" (1500 AU) from center. This structure most likely comprises a precessing outflow, which may be driven by a recently reported third protostellar component in L1551 IRS5. Gravitational interactions between this protostellar component and its more massive neighbor(s) may be causing the circumstellar disk and hence outflow of this component to precess.

2.16. Evidence for the Disintegration of Young Stellar Systems at Millimeter Wavelengths

Luis Zapata (Max-Planck-Institut fuer Radioastronomie, Germany), Luis F. Rodríguez (Centro de Radioastronomía y Astrofísica, UNAM, México), Paul Ho (Academia Sinica Institute of Astronomy and Astrophysics, Taiwan and Harvard-Smithsonian Center for Astrophysics, USA), Karl Menten and Johannes Schmid-Burgk (Max-Planck-Institut fuer Radioastronomie, Germany)

We present recent arcsecond resolution (∼3") CO[2→1] line observations made with the Submillimeter Array (SMA) in mosaicing mode toward the remarkable molecular outflow in the Orion BN/KL star-forming region. Our observations resolve the CO[2→1] molecular content of innermost part of this expanding structure into several very well-defined “jet-like” feature fragmenting into “bullets”. Connecting the positions of the molecular bullets allow us for the first time to pinpoint the origin of the KL outflow which we find to be coincident within the errors with the position from where the radio and infrared sources BN, I and n were ejected 500 years ago, suggesting a close relationship between both events. This result supports the possibility that the BN/KL outflow
was produced by the disintegration of a young stellar system. Finally, we will show images of some other molecules that could be tracing the remains of this explosive event.


3.1. Tracing the earliest stages of massive star formation in G14.2-0.60

Gemma Busquet (Departament d’Astronomia i Meteorologia, Universitat de Barcelona, Barcelona, Spain), Qizhou Zhang (Harvard-Smithsonian Center for Astrophysics. Cambridge, USA), Robert Estalella (Departament d’Astronomia i Meteorologia, Universitat de Barcelona. Barcelona, Spain), Paul T.P. Ho (Harvard-Smithsonian Center for Astrophysics. Cambridge, USA; Academia Sinica Institute of Astronomy and Astrophysics, Taipei, Taiwan), Thushara Pillai (Harvard-Smithsonian Center for Astrophysics. Cambridge, USA), Aina Palau (Laboratorio de Astrofísica y Exoplanetas, Centro de Astrobiología (INTA-CSIC). Madrid, Spain)

The Infrared Dark Cloud G14.2-0.60, located at a distance of 2.5 kpc, is a perfect laboratory to study the initial conditions for massive star and cluster formation. We conducted high angular resolution observations with the SMA in the compact and extended configuration in several molecular lines, including molecular outflow tracers and deuterated molecules, and in the continuum mode. The 1.2 mm continuum emission reveals a cluster of 15 millimeter sources deeply embedded in the high-density gas, with masses ranging from $\sim 0.9 M_\odot$ up to $25 M_\odot$. The molecular line data shows that deuterated species such as DNC (3–2) and DCO$^+$ (3–2) are enhanced toward this region. In addition, we have discovered two high-velocity CO (2–1) molecular outflows arising from two different millimeter condensations, indicating that active star formation is taking place.

3.2. Search for Primordial Mass Segregation in Protocluster Cores

J. M. Carpenter and L. Perez (Caltech)

Infrared Dark Clouds (IRDC) are cold, dense regions that are seen as extinction features against the bright mid-IR Galactic background. IRDCs harbor compact cores which may be the precursors to stellar clusters. The Combined Array for Research in Millimeter-Wave Astronomy (CARMA) presents an exceptional opportunity to study in detail the structure and dynamics of these proto-cluster cores at high angular resolution. We present CARMA continuum observations of 22 cores, selected from the dense cores found in the Cygnus-X region (Motte et al. 2007) and from the IRDC cores survey of Rathborne et al. (2006). The objective of this study is to establish the presence of mass segregation at the formative stage of a stellar cluster. The derived mass for the compact clumps detected with CARMA range between a few solar masses to $\sim 200 M_\odot$, which indicates that they can potentially form high mass stars. We found that for the majority of the IRDC cores, the mass of the clumps found in their interiors encompass a large fraction of the total mass of the core.

3.3. The LMC as a Massive Star Formation Laboratory: The Case of N44

C.-H. R. Chen (University of Virginia, Charlottesville, Virginia, USA), J. P. Seale, L. W. Looney, T. Wong, Y.-H. Chu, and R. A. Gruendl (University of Illinois, Urbana, Illinois, USA), and J. Ott (National Radio Astronomy Observatory, Socorro, New Mexico, USA)

The recent Spitzer mid-IR observations revealed a large number of individually resolved massive young stellar objects (YSOs) in the Magellanic Clouds, providing an excellent chance to study massive star formation with metallicity and galactic environment different from the Milky Way. Using Spitzer and complementary high-resolution ground-based data, we have identified 60 YSOs in the LMC HII complex N44, modeled their spectral energy distributions, and found that these YSOs span a range of mass from a few to $\sim 45 M_\odot$, as well as a range of evolutionary stage from highly embedded to retaining only remnant circumstellar material (Chen et al. 2009). We have obtained new HCN and HCO$^+$ observations with Australia Telescope Compact Array of two main molecular cores in N44, to investigate (1) Where the dense molecular gas is and how it correlates with YSOs at different evolutionary stages,
and (2) What the relationship is between molecular clump properties and YSO masses. In this poster we present the preliminary results of the N44 study.

3.4. Origin of high-mass stars and clusters in DR21(OH)

T. Csengeri, S. Bontemps, F. Motte, N. Schneider, Ph. Andre (SAp-IRFU / AIM-CNRS, CEA Saclay), F. Gueth (IRAM Grenoble), P. Hennebelle (ENS Paris)

We study the DR21 filament located in the Cygnus-X star forming region - one of the closest sites hosting high-mass star formation, where significant amount of the gas is concentrated at very high density. With single-dish (IRAM 30m) data we study the properties of the collapsing filament on large scale (1 pc), while with interferometric data (PdBI) we obtain the distribution of matter and the kinematics on smaller scale (0.01 pc). Therefore we aim to understand: (1) the initial conditions of the collapsing filament, which forms massive protostars; (2) to study the fragmentation and the kinematic properties of individual massive condensations on small scales; (3) to follow the link between the protostars and their close environment to test different theoretical views for their evolution.

3.5. High resolution mm line and continuum observation of massive disk candidates

C. Fallscheer and H. Beuther (MPIA Heidelberg, Germany), Q. Zhang, T.K. Sridharan and E. Keto (Harvard-Smithsonian CfA, USA), and J. Sauter and S. Wolf (University of Kiel, Germany)

We have obtained multiple data sets from the SMA, PdBI, and IRAM 30m telescope of the Infrared Dark Cloud IRDC 18223-3, and the somewhat more evolved High-Mass Protostellar Object IRAS 18151-1208 in order to search for clues regarding the role of rotation and disks in high mass star formation. These observations allow us to compare the central-most regions surrounding the embedded continuum source at different evolutionary stages of the formation process. Toward both regions we see rotational structures perpendicular to the molecular outflows. Continuum and line radiative transfer modeling of the observed disk-like structures is underway.

3.6. Linking pre- and proto–stellar objects in the intermediate-/high-mass star forming region IRAS05345+3157

F. Fontani (ISDC & Observatoire de Geneve, Versoix, Switzerland), P. Caselli (University of Leeds), T.L. Bourke and Q. Zhang (Harvard-Smithsonian Center for Astrophysics)

To better understand the initial conditions of the high-mass star formation process, it is crucial to study at high-angular resolution the morphology, the kinematics, and eventually the interactions of the coldest condensations associated with intermediate-/high-mass forming (proto)clusters. This work studies the cold condensations in the intermediate-/high-mass proto-cluster nearby IRAS 05345+3157, focusing the attention on the interaction with the other objects in the cluster. We have performed millimeter high-angular resolution observations, both in the continuum and several molecular lines, with the PdBI and the SMA. In a recent paper, we have already published part of these data. The main finding of that work was the detection of two cold and dense gaseous condensations, called N and S (masses 2 and 9 M⊙), characterised by high values of the deuterium fractionation (∼ 0.1 in both cores) obtained from the column density ratio N(N2D+)/N(N2H+). The present work give a full report of the observations, and a complete analysis of the data obtained. The millimeter maps reveal the presence of 3 cores inside the interferometer fields of view, called C1-a, C1-b and C2. All of them are not associated with cores N and S. C1-b is very likely associated with an early-B newly formed ZAMS star embedded inside a hot-core, while C1-a is more likely associated with a class 0 intermediate-mass protostar. The nature of C2 is unclear. Both C1-a and C1-b are good candidates as driving sources of a powerful 12CO outflow, which strongly interacts with N, as demonstrated by the velocity gradient of the gas along this condensation. The study of the gas kinematics across the source indicates a tight interaction between the deuterated condensations and the sources embedded in the millimeter cores. For the nature
of N and S, we propose two scenarios: they can be low-mass pre–stellar condensations or 'seeds' of future high-mass star(s).

### 3.7. Very Small HII Regions Embedded in Massive Accretion Flows

R. Galvan-Madrid, Q. Zhang, and E. Keto (Harvard-Smithsonian Center for Astrophysics), Luis F. Rodriguez, and Stan Kurtz (Centro de Radioastronomia y Astrofisica, UNAM), Paul T. P. Ho (ASIAA)

We present preliminary results of an SMA+VLA study of a small sample of hypercompact and small ultracompact HII regions with evidence of accretion flows surrounding them. Molecular-line observations at a resolution of a few arcseconds reveal motions in the natal cores indicative of rotation, infall, and/or outflow. Sub-arcsecond resolution data show that these regions are often a small group of massive (proto)stars, usually at different evolutionary stages. The hypercompact HII regions with positive spectral index from cm to mm wavelengths are the most compact and most embedded, and spectral index modelling suggests the presence of density gradients in the ionized gas. These regions are also surrounded by flattened molecular envelopes with evidence of rotation, infall, and/or outflow at scales smaller than 0.1 pc, and present large, organized motions in the ionized gas at scales of order 0.01 pc.

### 3.8. Massive Star Formation: Where should ALMA look?

Hill, T. (University of Exeter, Exeter, UK), Cunningham, M. R. and Burton M. G. (University of New South Wales, Sydney, Australia), Longmore, S. N. (Center for Astrophysics, USA), and Minier, V. (CEA/Saclay, France)

With the advent of new generation (sub)millimetre telescopes, such as the state-of-the art Atacama Large Millimeter Array (ALMA), the investigation of massive star formation regions in the Galaxy will undergo a major transformation. High resolution submillimetre observations with ALMA will allow many of the outstanding questions surrounding massive star formation to be addressed, including the details of how high-mass stars form as well as the role of turbulence and stellar feedback in these processes. In the meantime it is essential to identify the most suitable candidates for study with ALMA. Through a millimetre continuum emission study of massive star formation regions in the Galaxy, we have identified a large number of sources that could represent the earliest stages of massive star formation. Spectral energy distribution modelling and analysis indicates that these 'mm-only' cores are excellent candidates for early stage protostars or massive young stellar objects. We present here the results of a large-scale high-sensitivity spectral line investigation of these millimetre continuum cores, initiated to ascertain their physical and chemical properties and ultimately to address whether they display evidence of massive star formation and thus whether they are indicative of the earliest stages of massive star evolution.

### 3.9. Unveiling the main heating sources in the Cepheus A HW2 star cluster

I. Jiménez-Serra (School of Physics & Astronomy, The University of Leeds, Leeds, UK), J. Martín-Pintado (Centro de Astrobiología a (CSIC/INTA), Madrid, Spain), P. Caselli (School of Physics & Astronomy, The University of Leeds, Leeds, UK), S. Martín (Harvard-Smithsonian Center for Astrophysics, Cambridge, USA), A. Rodríguez-Franco (Centro de Astrobiología a (CSIC/INTA), Madrid, Spain), C. Chandler (National Radio Astronomy Observatory, Socorro, USA), and J.M. Winters (Institut de Radio Astronomie Millimétrique, Grenoble, France)

We present high angular resolution (beam of 0.33") images of the $J=27\rightarrow26$ line from several vibrational levels ($v_7=1$ and $v_6=1$) of HC$_3$N toward the Cepheus A HW2 star forming region. These images reveal the two main heating sources in the cluster: one centered in the disk collimating the HW2 radio jet (the HW2 disk), and the other associated with a hot core at 0.3" northeast HW2 (the HC). This constitutes the first detection of vibrational excited emission of HC$_3$N in a protostellar disk. We derive the temperature profiles in the two objects from the excitation of HC$_3$N along the HW2 disk and across the HC. These profiles reveal that both objects are centrally heated and show temperature gradients. The inner and hot-
ter regions have temperatures of 350 K and 270 K for the HW2 disk and the HC, respectively. In the cooler and outer regions, the temperature drops to 250 K in the HW2 disk, and to 220 K in the HC. The estimated luminosity of the heating source of the HW2 disk is $\sim 2.2 \times 10^4 L_\odot$, and $\sim 3000 L_\odot$ for the HC. The most massive protostar in the HW2 cluster is the powering source of the HW2 radio jet. We discuss the formation of multiple systems in this cluster. The proximity of the HC to HW2, and the different stages of evolution of these objects, suggest that the HC and the HW2 source likely form a binary system of B stars.

3.10. Molecular clouds and star formation in the Magellanic Clouds

Kawamura, A., Mizuno, Y., Muller, E., Yamamoto, H., Okuda, T., Mizuno, A., Fukui, Y. (Nagoya University, Japan), Onishi, T. (Nagoya University, Japan, and Osaka Prefecture University, Japan), Minamidani, T. (Hokkaido University, Japan), Mizuno, N., Ezawa, H., Yamaguchi, N., Kohno, K., Hasegawa, T., Tatematsu, K. (National Astronomical Observatory, Japan), Kohno, K. (University of Tokyo, Japan), Stutzki, J. (University of Cologne, Germany), Klein, U., Bertoldi, F. (University of Bonn, Germany), Koo, B. C. (Seoul National University, Korea), Rubio, M. (Universidad de Chile, Chile), Burton, M. (University of New South Wales, Australia), Benz, A. (ETH Zurich, Switzerland), Ott, J. (NRAO, USA, and Caltech Astronomy, USA), Wong, T. (University of Illinois, USA), Hughes, A. (ATNF/CSIRO, Australia, and Swinburne University of Technology, Australia), and NANTEN2 team

We have made a catalog of about 300 molecular clouds in the Large and Small Magellanic Clouds through the 12CO(1-0) observations by NANTEN, a 4 m telescope at Las Campanas Observatory in Chile. We have utilized the catalog of GMCs to compare the cloud distribution with signatures of massive star formation, stellar clusters, and classical HII regions. We find that the molecular clouds are classified into three types according to the associated activities of massive star formation; Type I shows no signature of massive star formation, Type II is associated with relatively small HII region(s) and Type III with both HII region(s) and young stellar cluster(s). We have been extending our observations to higher transition lines in CO and its isotopes as well as CI in submm with higher resolution by NANTEN2 and ASTE. In particular, a detailed study of the clumps in the N159 region, an active site of massive star formation in the Large Magellanic Cloud, has been made. The 12CO (4-3) emission is used for excitation calculations by combining the other transitions of the 12CO (1-0, 2-1, and 3-2) as well as 13CO and the temperatures and densities of the clumps are determined to be $\sim 70-80K$ and $\sim 3 \times 10^3 \text{ cm}^{-3}$ in the active star forming region in the North and $\sim 30K$ and $\sim 1.6 \times 10^3 \text{ cm}^{-3}$ in the Southern region without active star formation.

3.11. Outflows from Newly-Formed Massive Stars

Kee-Tae Kim (Korea Astronomy and Space Science Institute)

Compared to low-mass star formation, little is known about the formation process of high-mass stars. It is still debated whether high-mass stars form in a manner qualitatively similar to low-mass stars, and there are two major competing models: accretion via disks and coalescence of low-mass (proto)stars. In order to distinguish between the two, we carried out high-resolution molecular line observations and near-infrared H2 narrow-band imaging of several high-mass YSOs. We will present the results and discuss the implications.

3.12. Properties of Supercritical Massive Cores

D. Li, N. Chapman, P.-F. Goldsmith, and T. Velusamy (Jet Propulsion Laboratory, California Institute of Technology), and Q. Zhang and C. Qi (Harvard-Smithsonian Center for Astrophysics)

Based on surveys of submillimeter continuum and spectroscopy toward the Orion molecular clouds (Li et al. 2003, 2007, Velusamy et al. 2008), we have identified a sample of massive cores that are likely supercritical. The closeness of Orion and the resolving power of interferometers provide a unique opportunity to study these cores down to the thermal Jeans level, which has not been possible for massive cores. We accomplish
this by imaging the high density tracer N2H+ using CARMA and SMA. With resolution ranging from 1 to 3 arcsec of different rotational transitions of this tracer, detailed structures of cores are revealed on scales meaningful to individual star forming sites. Combined with analysis of multiband dust continuum involving far infrared data from our Spitzer GO program, these studies provide accurate measurement of the mass and dynamics. These massive cores in Orion have a flatter mass function than the Salpeter IMF and show signs of collapse.

3.13. Cluster and Massive Star Formation in Protostellar Outflow-Driven Turbulence

Z.-Y. Li (University of Virginia, USA), Fumitaka Nakamura (Niigata University, Japan), Peng Wang and Tom Abel (Stanford University, USA)

The majority of stars, including most if not all massive stars, are formed in clusters. In crowded regions of cluster and massive star formation, feedback from protostellar outflows is expected to be especially important. In this talk, I will first demonstrate that protostellar outflows of strength in the observed range can replenish the turbulence dissipated in typical cluster-forming dense clumps, and that the majority of cluster members are formed in a protostellar outflow-driven turbulence. I will then present the results of our recent high-resolution AMR (adaptive mesh refinement) MHD simulations of cluster formation that include both sink particles and protostellar outflows, focusing on the mass accretion rates onto stars, especially massive stars. We find that the massive stars in our simulations are formed neither from pre-existing dense cores nor through Bondi-Hoyle type accretion; their formation is controlled by the global dynamics of the cluster-forming clumps, which are strongly affected by protostellar outflows. We will discuss the implications of this picture of outflow-regulated cluster and massive star formation for high-resolution observations, especially with ALMA.

3.14. Massive star formation within the collapsing protoclusters in W43

Q. Nguyen-Luong, F. Motte, N. Schneider (AIM, Service d’Astrophysique, CEA Saclay, France), S. Bontemps (Observatoire de Bordeaux, France)

W43 is an exceptionally active star-forming region which harbors a starburst cluster and a very dense and massive molecular complex at a distance ~6 kpc. It appears as the second strongest region in $^{13}$CO line and 870 $\mu$m continuum emission after the Galactic center. Single-dish observations of this molecular complex have revealed that more than a dozen of massive stars ($M > 10 M_\odot$) are actually forming. With the IRAM 30m telescope, the two brightest and most massive protoclusters have been observed to be rapidly contracting (infall speed of several km/s) over parsec scales. Using the IRAM PdBI interferometer for follow-up observations, we probe the structure and kinematics of these two protoclusters to a deeper and smaller scale down to a ~ 0.1 pc scale. We will here present our preliminary results, among which the infall velocity field we have followed from the protocluster down to the dense core scales.

3.15. Temperature and Density Distributions in the Two Giant Molecular Clouds toward Westerlund 2

A. Ohama, N. Furukawa, J. Dawson, A. Kawamura, H. Yamamoto, T. Onish and Y. Fukui (Department of Physics and Astrophysics, Nagoya University), and N. Mizuno (National Astronomical Observation of Japan)

Westerlund 2 (Wd2) is a super star cluster associated with HII region (RCW49) at the Carina arm. It consists of twelve massive O-type stars and two Wolf-Rayet stars, with an estimated age of 2 - 3 million years and having a total stellar mass of several thousands solar mass confined within one pc.

In this work, we have carried out observation of 12CO J=2-1 emission and 13CO J=2-1 emission with NANTEN2 telescope. We examine the intensity ratio of these traces, incorporating observations of the CO J=1-0 with NANTEN telescope, and use LVG analysis to estimate physical properties of the detected molecular gas.

We report the discovery of two giant molecular clouds, named after their systemic LSR velocities
as the 4 km s⁻¹ cloud and 16 km s⁻¹ cloud. The morphology of these clouds correlated well with Spitzer IRAC image. We find that the intensity ratio of CO J=2-1 and 1-0 is as high as 1.4 1.5 at the edge of the 4km s⁻¹ cloud. We here present distributions of temperature and density in the two GMCs as derived from a LVG analysis of the CO J=2-1 and 1-0 transitions. The results may indicate the shocked region between the molecular gas and the stellar wind or the UV from Wd2. We will present the evidence that these molecular clouds are associated with super star cluster Westerlund 2.

3.16. Spectral Energy Distributions of 6.7 GHz methanol masers

J. D. Pandian (Max-Planck-Institut für Radiologieamton, Bonn, Germany), E. Momjian (NRAO Socorro, USA), Y. Xu (Purple Mountain Observatory, China), K. M. Menten (Max-Planck-Institut für Radiologieamton, Bonn, Germany), and P. F. Goldsmith (Jet Propulsion Laboratory, Pasadena, USA)

We present spectral energy distributions (SEDs) of a flux limited sample of 6.7 GHz methanol masers, which are thought to be signposts of early phases of massive star formation. To obtain constraints on the age of the massive young stellar objects associated with the masers, we obtained 3.6 cm, 1.3 cm and 7 mm continuum data with the VLA at comparable angular resolution towards a sample of 20 methanol masers selected from the Arecibo Methanol Maser Galactic Plane Survey. The emission at these wavelengths is dominated by thermal bremsstrahlung, whose turn-over frequency is correlated to the age of the young stellar object. More than half of the methanol masers in our sample have no emission at 3.6 cm and 1.3 cm, while the spectral index of the majority of the remaining sources is consistent with optically thick free-free emission. Most sources were detected at millimeter and submillimeter wavelengths using the IRAM-30 meter and APEX telescopes respectively. This work shows that methanol masers are mostly associated with phases of massive star formation prior to the formation of a hypercompact HII region, in which the HII region is pinched off by accretion.

3.17. Implications for small-scale clumpiness in massive cores

L. Pirogov and I. Zinchenko (Institute of Applied Physics, Russian Academy of Sciences, Nizhny Novgorod, Russia)

Massive molecular cloud cores are clumpy on different spatial scales probably down to the scales unresolved by single dish telescopes. A large number of unresolved clumps in the beam could give detectable intensity fluctuations (ripples) on line profiles obtained with high signal-to-noise ratios. Such ripples have been detected on the HCN(1–0), HCO⁺(1–0), CO(1–0) and marginally on the CS(2–1) line profiles observed towards distinct positions in selected high-mass star-forming regions. A number of clumps in the beam is determined with a help of analytical model. Physical parameters of distinct clumps are derived from detailed calculations in the framework of clumpy cloud model.

3.18. High angular resolution studies of Infrared Dark Cloud cores: understanding the very earliest stages in the formation of high-mass stars and clusters

J. M. Rathborne, G. Garay (Departamento de Astronomía, Universidad de Chile, Chile), J. M. Jackson, E. T. Chambers (Institute for Astrophysical Research, Boston University, U.S.A), and Q. Zhang and S. Longmore (Harvard-Smithsonian Center for Astrophysics, U.S.A)

Infrared Dark Clouds are a distinct class of interstellar gas cloud identified as dark extinction features seen in silhouette against the bright Galactic background at mid-IR wavelengths. Our recent 1.2 mm continuum emission survey of IRDCs reveal many compact (¡ 0.5 pc) and massive (10 to 2100 Msun) cores within them. These pre-stellar cores hold the key to understanding IRDCs and their role in star formation. About 1/3 of these cores show evidence for active star-formation; shocked gas, outflows, and embedded protostars. The remaining 2/3 of these cores show no signs of active star formation and may be massive starless cores. Here we present recent high angular resolution molecular line maps and sub-
mm continuum images toward six high-mass cores obtained with the IRAM Plateau de Bure Interferometer and the SMA. The mm/submm continuum images elucidate the sub-parsec scale structure, and reveal that the cores are typically resolved into multiple protostellar condensations. A comparison of the ratios of the gas masses to the Jeans masses for IRDCs, cores, and condensations, provides broad support for the idea of hierarchical fragmentation. The close proximity of multiple protostars of disparate mass indicates that these IRDC cores are in the earliest evolutionary states in the formation of stellar clusters. In two cases, however, we find that the cores are unresolved at sub-arcsec angular resolution and that their molecular line spectrum reveals numerous emission lines from complex molecules. Such a rich molecular line spectrum from a compact region indicates that these contain a hot molecular core, an early stage in the formation of a high-mass protostar. Together, these data support the idea that the earliest stages of high-mass star and cluster formation occurs within IRDCs.

3.19. An outflow in G8.67-0.36

Z. Ren, T. Liu, and Y. Wu (Peking University)

Methanol masers uniquely accompany high-mass star formation regions. We have been working on mapping of methanol maser sources via single dish telescopes and high resolution observation with SMA. In one source G8.68-0.36, a single dense core is found in its central region. Strong emission of N2H+(3-2) is detected, indicating an active pre-stellar core with N-bearing molecules being synthesized. H2CO (4-3) images of different velocities present two outflow lobes with blue and red shift. The data we have shows that it is a high mass pre-stellar core with evident kinematic activities.

3.20. slow outflow motion in a High-mass star formation core

Z. Ren, Y. Wu, T. Liu et al. (Peking University)

will submit before deadline

3.21. Fragmentation in the Massive Star-Forming Region IRAS 19410+2336: a Core Mass Function resembling the IMF

J.A. Rodón and H. Beuther (Max-Planck-Institut für Astronomie, Heidelberg, Germany), and P. Schilke (Max-Planck-Institut für Radioastronomie, Bonn, Germany)

Massive stars are known to form in clustered mode. During their earliest evolutionary stages, they are embedded within their natal cores. Using high-spatial-resolution interferometric dust continuum observations, we disentangle once more the cluster-like structure of the massive star-forming region IRAS 19410+2336, and derive its Core Mass Function (CMF). This time we surmount caveats of similar previous works, most important, using molecular line emission we determine the temperature of the detected cores. Having a more reliable value for the temperature, the core masses can be better determined, obtaining a better and more accurate CMF. This CMF is consistent with the stellar Initial Mass Function, implying that the fragmentation of the initial massive cores may determine the IMF and the masses of the final stars.

3.22. DNC/HNC Ratio in High-Mass Star-Forming Regions

T. Sakai (Nobeyama Radio Observatory, National Astronomical Observatory of Japan, Nagano, Japan), N. Sakai, S. Shiba, S. Yamamoto (The University of Tokyo, Japan), and T. Hirota (National Astronomical Observatory of Japan, Tokyo, Japan)

In order to investigate formation processes of high-mass protostars, it is indispensable to understand the initial physical conditions of their parent clouds. With this in mind, we have carried out a survey of the HN$_{13}$C $J$=1–0 and DNC $J$=1–0 lines toward high-mass star forming regions, including infrared dark clouds (IRDCs), high-mass protostellar objects (HMPOs), and hot cores (HCs), by using the Nobeyama Radio Observatory 45 m telescope. We have successfully detected the HN$_{13}$C and DNC lines toward all the observed objects. We have found that the DNC/HN$_{13}$C ratio is different even among the objects in a similar evo-
lutionary stage. For example, the DNC/HN\textsuperscript{13}C peak intensity ratio is about four times higher toward I\textsuperscript{18264-1152} (∼0.8) than toward I\textsuperscript{18089-1732} (∼0.2), where I\textsuperscript{18089-1732} and I\textsuperscript{18264-1152} are recognized as HMPOs and are associated with CH\textsubscript{3}OH masers. Since the DNC/HNC ratio is thought to vary with a timescale of 10\textsuperscript{5} yr in a hot gas phase, the DNC/HN\textsuperscript{13}C ratio observed toward the HMPOs could reflect the deuterium fraction in a cold starless phase. Thus, the difference in the DNC/HN\textsuperscript{13}C ratio may reflect the difference in the initial condition. In this talk, we will discuss the origin of the difference in the DNC/HNC ratio in detail, and also discuss future observation plans.

### 3.23. SMA Observation of NGC2264 MMS3, a Candidate for 'High-Mass Class 0' Protostar

O. Saruwatari and N. Sakai (The University of Tokyo), T. Sakai (NRO), S.-Y. Liu and N.-Y. Su (ASIAA), S. Yamamoto (The University of Tokyo)

The NGC2264 IRS1 region is a nearby high-mass star forming region lying at a distance of 760 pc, which involves a bright millimeter-wave continuum source, MMS3. MMS3 has been believed to contain a high-mass protostar because of its large mass (48 M\textsubscript{☉}). A hot core molecule, HCOOCH\textsubscript{3}, is detected around MMS3 (Sakai et al. 2007). Although a compact outflow of CS(J=5-4) is reported by Schreyer et al. (1997), it is not clear whether the driving source is really MMS3, because of poor spatial resolution of their observation. In the present study, we have conducted a high resolution observation of the molecular outflow with the CO(J=2-1) and CH\textsubscript{3}OH(J\textsubscript{k}=5\textsubscript{k}-4\textsubscript{k}) lines using SMA.

A compact outflow obviously associated with MMS3 has been detected with the both lines, whose dynamical age is as young as 300 - 4000 yr. Considering that no Spitzer source is associated with MMS3, it is highly likely that MMS3 contains a very young high-mass protostar corresponding to a 'Class 0' object. Such a source is very novel, and hence, MMS3 would be a good target for understanding of an initial stage of high-mass star formation.

In our observation, the CH\textsubscript{3}OH outflow is mainly distributed just outside the CO outflow, indicating that CH\textsubscript{3}OH exists in a post-shock layer caused by an interaction between the outflow and an ambient gas. On the other hand, the HCOOCH\textsubscript{3} distribution has no relation with the outflow, suggesting that the outflow is not a direct origin of HCOOCH\textsubscript{3}. The HCOOCH\textsubscript{3} clump in the MMS3 region is located toward rather perpendicular direction to the outflow, just as in the case of Orion KL. An origin of the similarity is discussed.


### 3.24. The intermediate mass star-forming region IRAS 00117+6412: Three intermediate mass YSOs in the making

Álvaro Sánchez-Monge (Departament d’Astronomia i Meteorologia, Universitat de Barcelona, Barcelona, Spain), Aina Palau (Laboratorio de Astrofísica Estelar y Exoplanetas, Centro de Astrobiología (INTA-CSIC), Madrid, Spain), Gemma Busquet, Robert Estalella (Departament d’Astronomia i Meteorologia, Universitat de Barcelona, Barcelona, Spain), Qizhou Zhang (Harvard-Smithsonian Center for Astrophysics, Cambridge, USA), and Paul T. P. Ho (Harvard-Smithsonian Center for Astrophysics, Cambridge, USA), (Academia Sinica Institute of Astronomy and Astrophysics, Taipei, Taiwan)

IRAS 00117+6412, located at a distance of only 1.8 kpc, is an intermediate mass star-forming region appropriate to study the clustered mode of star formation. We conducted high-resolution and high-sensitivity observations with the PdBI, SMA and VLA arrays to study the different young stellar objects (YSOs) embedded in this region through continuum, dense gas and molecular outflow emission. We present here the first results obtained from these observations. The region is dominated by three main YSOs in different evolutionary stages: (1) a shell-like ultracompact HII region produced by a B2 star at the border of a cloud with multiple subcondensations, (2) a dust compact source embedded in dense gas with near infrared emission, and powering one or more CO bipolar outflows, and (3) a compact dust source
with no infrared neither outflow emission, but with signposts of rotation and infalling motions.

3.25. SMA Observations of the UC H\textsc{ii} Region G5.89-0.39

Y.-N. Su, S.-Y. Liu, K.-S. Wang (Academia Sinica Institute of Astronomy and Astrophysics, Taipei, Taiwan), Y.-H. Chen (Department of Physics, National Taiwan University, Taipei, Taiwan), and H.-R. Chen (Institute of Astronomy and Department of Physics, National Tsing Hua University, Hsinchu, Taiwan)

We present observations of the CH$_3$CN (12–11) emission at a resolution of ∼2″ toward the high-mass star forming region G5.89−0.39 with the Submillimeter Array. The integrated CH$_3$CN emission reveals a cavity of dense molecular gas centered at the H\textsc{ii} region G5.89−0.39 and exhibits dense and warm molecular gas in its periphery, consistent with the picture of a dust and molecular gas free cavity within the H\textsc{ii} region. The CH$_3$CN gas peaks at three dust condensations previously detected in sub-millimeter continuum. With the population diagram analysis, we estimate the temperature of the molecular gas and present spatial distributions of temperature toward G5.89−0.39. The deduced temperatures range from ∼40 K to ∼150 K. We discuss illumination mechanisms of the warm dense gas and conclude that the H\textsc{ii} region powering star provides the majority energy for heating the surrounding dense gas.

3.26. Small scale structure of cloud surface perturbed by nearby HII region

Kengo Tachihara (NAOJ)

For molecular cloud evolution and star formation, supersonic interstellar turbulence is one of the key fundamental elements. Previous studies on dense core stability, it is shown that cores dominated by larger internal turbulent motion tend to be less active in star formation having longer timescale of contraction. However we still do not know yet what interstellar turbulence originates and how it is sustained long time. Koyama & Inutsuka proposed an idea that thermal instability on a compressed cloud layer generates turbulent motion and it fragments into small cloudlets. In order to verify this idea we made high-resolution $^{12}$CO survey on a cloud boundary interacting with HII region by the Nobeyama 45m telescope. As a result, small-scale (∼10000 AU) cloud structures with complex velocity fields are detected.

3.27. A high resolution study of the core JCMT 18354-0649S

T. Liu, Y. Wu, Z. Ren and X. Guan (Astronomy Dep., Peking Univ.), Q. Zhang (Harvard-Smithsonian Center for Astrophysics), and M. Zhu (JAC/NRCC, Herzberg Institute of Astrophysics)

Core JCMT 18354-0649S is a high-mass protostellar object with both inflow and outflow according to previous single dish studies. We carried out an observation with the Submillimeter Array at 1.3 mm wavelength. The continuum revealed that the core has a diameter of less than 2″ and a mass of 127 $M_\odot$. HCN J=3-2 line profile exhibits collapse signature which is consistent with the result of the single dish observation. The profiles of the HCN J=3–2 lines also show high velocity gas. The HCN line wings are almost total at the blue or red side of the systematic velocity. Three outflow lobes are manifested on the HCN J=3–2 image. The parameters of the inflow and outflow are calculated. Our results suggest that an active high mass protostar is forming at the core center.

3.28. CO(1-0) mapping of four IRDCs

jianjun Zhou (Urumqi Observatory,NAOC, Urumqi city, Xinjiang, P.R. China)

IRDCs (Infrared dark clouds) are the sites of high mass star cluster formation, where very dense gas and relatively diffuse gas exist, multiline studies are necessary to probe their physical conditions and chemical evolution. NH$_3$ and CO are good probes of dense and diffuse gas respectively. We selected a sample of IRDCs that have been observed by NH$_3$, and made CO mapping using 13.7m millimeter radio telescope of Purple Mountain Observatory. We hope to get more detailed knowledge of their physical conditions and relative evolution. Here we report the result of CO mapping of 4 IRDCs.
3.29. W3-SE: a star forming core with high-energy outflow and infall

Lei Zhu (Harvard-Smithsonian Center for Astrophysics; Peking University, China), J.-H. Zhao (Harvard-Smithsonian Center for Astrophysics), M. Wright (University of California, Berkeley), and Y.-F. Wu (Peking University, China)

We report the results from the observations of W3-SE with the SMA, CARMA and JCMT. Located 2 kpc away, W3-SE is a molecular core SE of the active high-mass star formation region W3-Main. Based on the measurements of flux densities at mm/sub-mm along with the Spitzer data at mid-IR wavelengths, we have determined the SED of the dust emission from W3-SE. The SED can be fitted with a thermal dust model with two temperature components. Our best fitting suggests the presence of a major cold dust component with dust temperature of about 34 K and mass of about 180 solar mass, as well as a mid-IR bump indicating a small fraction of the dust which has been heated in the core. The observations of HCO+(1-0) line with the CARMA in an angular resolution of 6 arcsec suggest that multiple outflows are present in this core. In the SMA observations at 1.3 mm with an angular resolution of 2.5 arcsec, the dust core of W3-SE has been resolved into two components (SMA-1 and SMA-2) with comparable flux densities separated by about 4 arcsec. Molecular lines including HCN(3-2), HCO+(3-2), N2H+(3-2) and CH3OH lines toward the double core have also been observed with the SMA. Both HCN(3-2) and HCO+(3-2) lines show broad blue- and red-shifted spectral wings with velocities of about 40 km/s with respect to the systematic velocity of -39.0 km/s suggested by the peak velocity of the optically thin lines of CH3OH. We have imaged the blue- and red-shifted spectral wings, revealing a compact, high-velocity bipolar outflow ejected from SMA-1 in the direction perpendicular to the large scale outflow observed with both the SMA and the CARMA. From the lines including HCN(3-2), HCO+(3-2) and N2H+(3-2), we have detected self-absorption features toward SMA-1 which are red-shifted with respect to the systematic velocity, providing good evidences for high density molecular gas moving toward SMA-1.

4. Galactic Star Formation: Outflows and Jets

4.1. SMA high angular millimeter-submillimeter observations: dust in the heart of GGD27

M. Fernandez-Lopez and S. Curiel (Instituto de Astronomia, UNAM, Mexico City, Mexico.), J.M. Girart (Institut de Ciencies de l’Espai (CSIC-IEEC), Barcelona, Spain.), N. Patel (Harvard-Smithsonian CfA, Cambridge, USA.), and Y. Gomez (CRYA, UNAM, Morelia, Mexico.)

The GGD27 system, also known as HH 80-81, is one of the most powerful molecular outflows associated with a high mass star-forming region observed up to now. Here we report the detection of dust continuum emission at sub-arcsec/arcsec resolution with the SMA at 1.36 mm and 460 µm, respectively. These observations reveal two compact dusty sources at 460 µm. One of them, SMM1, spatially coincides with the thermal radio continuum jet, located at the center of the powerful molecular outflow. The other source, SMM2, is located about 7" to the NE and spatially coincides with a weak radio continuum source and a water maser. The sub-arcsecond 1.36 mm observations show that both sources are compact, having sizes smaller than 1000 AU, which suggest that they are circunstellar disks around high mass protostars. The characteristics observed in both sources suggest that they are in different evolutionary stages.

4.2. Outflow - Core Interaction in Barnard 1

M. Hiramatsu, N. Hirano, S. Takakuwa (Academia Sinica Institute of Astronomy and Astrophysics, Taipei, Taiwan), and T. Hasegawa (National Astronomical Observatory of Japan, Tokyo, Japan)

In order to study how the outflows from protostars influence the physical and chemical conditions of the parent molecular cloud, we have studied the Barnard 1 (B1) main core, which harbors three class 0 and three class I sources, in the CO, CH3OH, and SiO lines using the NRO 45 m telescope. We have identified two CO outflows in this region; one is an elongated outflow from a class 0
protostar, B1-c, and the other is a rather compact bipolar outflow from a class I protostar, B1-a. In the western lobe of the B1-c outflow, both SiO and CH$_3$OH lines show broad redshifted wings having the terminal velocities of 25 km/s and 13 km/s, respectively. It is likely that the shocks caused by the interaction between outflow and ambient gas enhanced the abundance of SiO and CH$_3$OH in the gas phase. The total outflow energy input rate ($>5.0 \times 10^{-3}L_\odot$) is comparable to the energy loss rate ($8.8 \times 10^{-2}L_\odot$) through turbulence decay in the B1 main core, which indicates that the outflows can provide enough energy to maintain the turbulence in this region. In this poster we will also discuss possibilities of higher resolution observations of YSO clusters/groups. Such observations will help us to understand how the current star formation scenario in the isolated environment needs to be modified when the stars are formed in the cluster environment.

### 4.3. Extreme active molecular jet in L1448C


The protostellar jet driven by L1448C was observed in the SiO $J=8$–$7$ and CO $J=3$–$2$ lines and 350 GHz dust continuum at $\sim$1'' resolution with the Submillimeter Array (SMA). A narrow jet along the outflow axis was observed in the SiO and the high-velocity CO. The jet consists of a chain of emission knots with an inter-knot spacing of $\sim$2''(500 AU) and a semi-periodic velocity variation. These knots are likely to be the internal bow shocks in the jet beam that were formed due to the periodic variation of the ejection velocity with a period of $\sim$15–20 yr. The innermost pair of knots, which are significant in the SiO map but barely seen in the CO, are located at $\sim$1''(250 AU) from the central source, L1448C(N). Since the dynamical time for the innermost pair is only $\sim$10 yr, SiO may have formed in the protostellar wind through the gas-phase reaction or formed on the dust grain and directly released into the gas phase by means of shocks. It is found that the jet is extremely active with a mechanical luminosity of $>6 L_\odot$, which is comparable to the bolometric luminosity of the central source ($7.5 L_\odot$). The high mass-loss rate of $10^{-5} M_\odot$ yr$^{-1}$ suggests that the mass and the age of the central star are 0.02–0.07 $M_\odot$ and (2–7)$\times10^3$ yr, respectively. The CO $J=3$–$2$ map revealed the second outflow driven by the Spitzer source L1448C(S) located at $\sim$8.3''(2000 AU) from L1448C(N). Although L1448C(S) is brighter than L1448C(N) in the mid-IR bands, the momentum flux of the outflow from L1448C(S) is two or three orders of magnitude smaller than that of the L1448C(N) outflow.

#### 4.4. Shells, jets, and internal working surfaces in the molecular outflow

J. Santiago-García and M. Tafalla (Observatorio Astronómico Nacional (IGN), Madrid, Spain), D. Johnstone (NRC Canada, Herzberg Institute of Astrophysics, Victoria, Canada), and R. Bachiller (Observatorio Astronómico Nacional (IGN), Madrid, Spain)

We present Plateau de Bure CO($J=2$–$1$) and SiO($J=2$–$1$) observations of the extremely young and highly symmetric outflow from IRAS 04166+2706 in Taurus. We find that the outflow consists of two distinct components. At velocities $<10$ km s$^{-1}$, the gas forms two opposed, approximately conical shells that have the YSO at their vertex. These shells coincide with the walls of evacuated cavities and seem to result from the acceleration of the ambient gas by a wide-angle wind. At velocities $>30$ km s$^{-1}$, the gas forms two opposed jets that travel along the center of the cavities and whose emission is dominated by a symmetric collection of at least 7 pairs of peaks. The velocity field of this component presents a sawtooth pattern with the gas in the tail of each peak moving faster than the gas in the head. This pattern, together with a systematic widening of the peaks with distance to the central source, is consistent with the emission arising from internal working surfaces traveling along the jet and resulting from variations in the velocity field of ejection. We interpret this component as the true protostellar wind, and we find its composition consistent with a chemical model of such type of wind. Our results support outflow
wind models that have simultaneously wide-angle and narrow components, and suggest that the EHV peaks seen in a number of outflows consist of internally-shocked wind material.

### 4.5. Rotating molecular outflows: the young T Tauri star in CB26

R. Launhardt, Ya. Pavlyuchenkov, Th. Henning (MPIA, Heidelberg, Germany), F. Gueth, V. Pietu (IRAM, Grenoble, France), A. Dutrey, S. Guilloteau (Université Bordeaux and CNRS, France), and K. Schreyer (Astrophysical Institut, University Jena, Germany)

The disk-outflow connection is thought to play a key role in extracting excess angular momentum from a forming proto-star. Though jet rotation has been observed in a few objects, no rotation of molecular outflows has been unambiguously reported so far. We report new millimeter-interferometric observations of the edge-on T Tauri star - disk system in the isolated Bok globule CB26. The IRAM PdBI array was used to observe 12CO(2-1) with 1.5arcsec angular resolution. We use an empirical outflow model combined with 2-D line radiative transfer calculations to derive parameters of the outflow. The data reveal a collimated bipolar molecular outflow of total length 2000 AU, escaping perpendicular to the plane of the disk. Peculiar kinematic signatures suggest the outflow is rotating with the same orientation as the disk. CB26 is so far the most promising source to study the rotation of a molecular outflow. We compare CB26 to other similar sources and discuss possible strategies how outflow rotation can be detected and studied.

### 4.6. First Detection of a Bipolar Molecular Outflow from a Young Brown Dwarf

N. Phan-Bao (Academia Sinica Institute of Astronomy and Astrophysics, Taipei, Taiwan)

Studying the earliest stages in the birth of stars is crucial for understanding how they form. Brown dwarfs with masses between that of stars and planets are not massive enough to maintain stable hydrogen-burning fusion reactions during most of their lifetime. Their origins are subject to much debate in recent literature because their masses are far below the typical mass where core collapse is expected to occur. Based on SMA observations, we present the first detection of a bipolar molecular outflow from a young brown dwarf of 60 Jupiter mass, ISO-Oph 102 in rho Ophiuchi. Our results demonstrate that the bipolar molecular outflow operates down to brown dwarf masses, occurring in brown dwarfs as a scaled-down version of the universal process seen in young low-mass stars.

### 4.7. MHD Simulations of Accretion Disk Outflows From Low-Mass Stars

George B. Trammell and Zhi-Yun Li (University of Virginia, Charlottesville VA, USA)

Protostellar outflows are an integral part of the star formation process, as they provide feedback to the surrounding material in the forms of mass, energy, and momentum. They can also regulate the accretion rate and help determine the stellar rotation speed. I will present some early results of global 2D-MHD simulations that explore the nature of magnetically-driven accretion disk outflows around low-mass stars. I seek to understand which of the physical mechanisms and disk properties driving outflows has the most influence in determining the angular momentum transport, mass outflow rates, and velocity signatures at the larger scales currently accessible by observations, as well as to predict results at the smaller scales that will be accessible with ALMA. This will be important for learning more about the role of outflows in star formation, while also identifying important implications for the dynamics of accretion disks in these systems at the future sites of planet formation.

### 4.8. Emission Signatures from a Young Embedded Molecular Outflows

M. Yamada (Academia Sinica Institute of Astronomy and Astrophysics, Taipei, Taiwan), M.N. Machida and S. Inutsuka (Department of Physics, Kyoto University, Kyoto, Japan), and K. Tomisaka (National Astronomical Observatory of Japan, Mitaka, Japan)

We examine emission from a young protostellar object with three-dimensional ideal MHD simulations and non-local thermodynamic equilibrium
(non-LTE) line transfer calculations. To calculate emission field, we employed a snapshot result of MHD simulation having young bipolar outflows and a dense protostellar disk (a young circumstellar disk) embedded in an envelope. Synthesized line emission of two molecular species ($^{12}$CO and SiO) show that sub-thermally excited SiO lines as a high density tracer can better probe a complex velocity field of a young protostellar object, compared to fully thermalized $^{12}$CO lines. We find that since a young protostellar object evolves dynamically, infall, rotation, and outflow motions have similar speeds but different directions. The velocity field compound of these components introduces a great complexity in line emission fields through varying optical thickness and emissivity, such as double-horn profiles with various blue and red asymmetries. We find that one of the features that characterizes an outflow driven by magneto-centrifugal force appears clearly in velocity channel maps and intensity-weighted mean velocity (first moment of velocity). The somewhat irregular morphology of line emission at this youngest stage do not appear like a more evolved object such as young Class 0, even with high-resolution observation with the ALMA telescope. We will briefly show some results of imaging simulation for ALMA.

5. Protoplanetary Disks and Debris Disks

5.1. SMA Observation of a Very Low Luminosity Object

Chao-Ling Hung, Tao-Chung Ching and Shih-Ping Lai (National Tsing Hua University, Taiwan)

We present Submillimeter Array (SMA) observation of a Very Low Luminosity Object (VeLLO) SSTc2d J032839.10+310601.8 in Perseus. VeLLOs are believed to be the youngest YSOs hence provide a great opportunity to study the initial condition of star formation. Our result show a slightly flattened continuum at the position of YSO and the $\text{N}_2\text{D}^+$ emission has long axis $\approx 6000\text{AU}$ with the same elongation direction as continuum. The flattened $\text{N}_2\text{D}^+$ emission has a velocity gradient along the long axis direction, which may be an indicator for a rotating disk or pseudodisk. The $^{12}\text{CO}$, $^{13}\text{CO}$ and $^{18}\text{O}$ data hint the existence of velocity gradient, which is not consistent with the apparent outflow feature in Spitzer’s IRAC2 band. Therefore, we suggest that the outflow feature in IRAC2 may not come from SSTc2d J032839.10+310601.8, but from a nearby source IRAS03256+3055, in agreement with the observations by Hodapp et al. (2005). Future single dish observations are needed to recover the large scale structure in order to investigate the origin of the velocity gradient.

5.2. Model Predictions for ALMA: Spectroscopic Signatures of Planet Formation in HCO+ 7-6

Jenna L. Kloosterman (University of Arizona, Tucson, AZ), Desika Narayanan (Harvard-Smithsonian Center for Astrophysics, Cambridge, MA), Christopher K. Walker (University of Arizona, Tucson, AZ)

In the coming years the Atacama Large Millimeter Array (ALMA) will provide a new window into the physics of Gas Giant Planet (GGP) formation. With its unprecedented spatial resolution at submillimeter wavelengths ALMA will be able to observe deep within the region of planet formation in protoplanetary disks unobscured by optical starlight. By utilizing heterodyne receivers, ALMA will be able to be used to perform detailed dynamical studies of these protoplanetary environments. I am use the ”Turtlebeach” microturbulent radiative transfer code combined with recent 3-D hydrosimulations to search for signatures of protoplanet formation that will be observable with ALMA.

5.3. Submillimeter observation of the transition disk system of HD 135344

A-Ran lyo (Korea Astronomy and Space Science Institute, Daejeon, Korea), Nagayoshi Ohashi (Academia Sinica of Astronomy and Astrophysics, Taipei, Taiwan)

~17 Myr-old HD 135344 is suggested in the transition stage between primordial and debris disks. This disk system is suggested to have a large inner gap, R$\sim$45 AU, from the spectral energy distribution (SED) study, which might be involved the clear-up process due to the planet for-
mation. In this presentation, we provide results of the SubMillimeter Array (SMA) observations at 230 GHz.

5.4. Multi-technique observations and modeling of protoplanetary disks

*C. Pinte (University of Exeter, UK), F. Ménard (Laboratoire d’Astrophysique de Grenoble, France), and G. Duchêne (Laboratoire d’Astrophysique de Grenoble, France and UC Berkeley, USA)*

Most of the studies on circumstellar disks are based on models that emphasis on fitting either SEDs, scattered light images or (sub-)millimeter resolved maps. 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 gas properties, as well as their interactions. 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, polarisation maps, IR spectroscopy, X-ray spectrum, mm thermal emission maps, CO maps) will be presented.

5.5. Probing water line emission in protoplanetary disks

*D. R. Poelman (School of Physics & Astronomy, University of St. Andrews, North Haugh, St. Andrews KY16 9AD, UK), R. Meijerink and K. Pontoppidan (California Institute of Technology, Division of Geological and Planetary Sciences, MS 150-21, Pasadena, CA 91125), M. Spaans (Kapteyn Astronomical Institute, P.O. Box 800, 9700 AV Groningen, the Netherlands), and A. G. G. M. Tielens (Leiden Observatory, Leiden University, P.O. Box 9513, NL 2300 RA Leiden, the Netherlands)*

One of the most fundamental questions to date in modern astrophysics is how stars and planets form. Protoplanetary disk evolution and planet formation are closely entangled. Therefore, to understand their formation mechanisms, one first needs to develop a comprehensive picture of the physical and chemical conditions in protoplanetary disks. We present recent work in combining thermal-chemical models of proto-planetary disks with a molecular line radiative transfer program to investigate the diagnostic potential of the infrared lines of water.

6. Evolved Stars

6.1. Multiple Collimated Molecular Flows in the Young Planetary Nebula NGC 7027

*T. I. Hasegawa, Z.-Y. Haung, Dinh-Van-Trung, S. Muller, N. Hirano, J. Lim, M.-Y. Wang (Academia Sinica Institute of Astronomy and Astrophysics, Taipei, Taiwan), S. Kwok (University of Hong Kong, Hong Kong, PROC), A. Lyo (Korea Institute of Astrophysics, Korea), M. Mariappan (Aryabhatta Research Institute, India)*

The young planetary nebula NGC 7027 was observed in HCO$^+$ (3–2) and HCN (3–2) with the Submillimeter Array (SMA). The overall morpholgy of the HCO$^+$ emission is consistent with a thin photodissociation layer that encloses the central HII region. Several extruding components appear commonly in the HCO$^+$ and HCN observations. The extruding components are interpreted as multiple outflows. The bipolar outflows correspond to the high-velocity wings in the HCO$^+$ and HCN spectra from single-dish observations. In addition, SMA observations in CO (2–1, 3–2) show another bipolar outflow.

6.2. Millimeter spectral survey of IRC +10216

*J. H. He (Yunnan Astronomical Observatory, Chinese Academy of Sciences), Dinh-V-Trung and T. Hasegawa (Academia Sinica Institute of Astronomy and Astrophysics, Taiwan)*

We performed a millimeter spectral survey to the archetypal carbon star IRC +10216 between 131-160 GHz and 216-279 GHz, using ARO 10m and 12m telescopes. The resulted spectra can serve as a guide for further radio study of evolved stars.
6.3. The study of extended structures surrounding planetary nebulae by the Spitzer Telescope

C.-H. Hsia and S. Kwok (Department of physics, university of Hong Kong, Hong Kong, China)

Here we present initial results of our search for extended structures around the planetary nebulae (PNe) based on infrared data from the Infrared Array Camera (IRAC) of Spitzer Telescope. Morphologies of most of the sources at infrared wavelengths which contributed from warm dust continua or atomic forbidden emissions are different to these observed in the visible. We investigated two planetary nebulae (NGC 3242, NGC 7354), which were found to be surrounded by extensive ring/filament structures. The formation of these rings/filaments might be closely related to the asymptotic giant branch (AGB) phase mass loss and/or the interaction of the stellar outflows with the interstellar medium (ISM). Close investigation of them, indicate a kinematic age on the order of $10^4$ yrs. The mass loss history can be traced back to the late AGB phase of the evolution of the progenitors. The spacing between rings in our sample were found larger than the ones observed in proto-planetary nebulae. This suggests that mass loss increases at the end of the AGB phase.

6.4. Circumstellar H$_2$O in M-type AGB stars

M. Maercker (Department of Astronomy, Stockholm University), F.L. Schöier (Onsala Space Observatory), H. Olofsson (Department of Astronomy, Stockholm University), (Onsala Space Observatory)

Surprisingly high amounts of H$_2$O have recently been reported in the circumstellar envelope around the M-type AGB star W Hya. However, substantial uncertainties remain, as the required radiative transfer modelling is difficult due to high optical depths, sub-thermal excitation, the sensitivity to the combined radiation field from the central star and dust grains, and the uncertainties in the adopted collisional rate coefficients. We use a non-local, radiative transfer code based on the accelerated lambda iteration formalism to model the circumstellar H$_2$O emission towards six M-type AGB stars. ISO LWS spectra are used to constrain the models. For three of the stars spectrally resolved circumstellar H$_2$O($1_{10} - 1_{01}$) lines have been obtained using the Odin satellite. This provides additional strong constraints on the properties of circumstellar H$_2$O, in particular on the chemistry in the stellar atmosphere, the photodissociation in the outer envelope, and the velocity structure of the inner circumstellar envelope. Predictions for H$_2$O emission lines in the spectral range of the upcoming Herschel/HIFI mission indicate that these observations will be very important in this context, revealing critical information on the radiation field, chemistry, and dynamics in the inner envelopes of AGB stars.

6.5. IRC+10216’S INNERMOST ENVELOPE – THE ESMA’S VIEW

Shinnaga, Hiroko; Young, Ken H.; Tilanus, Remo P. J.; Chamberlin, Richard; Gurwell, Mark A.; Wilner, David; Hughes, A. Meredith; Yoshida, Hiroshige; Peng, Ruisheng; Force, Brian; Friberg, Per; Bottinelli, Sandrine; Van Dishoeck, Ewine F.; Phillips, Thomas G.

We used the Extended Submillimeter Array (eSMA) in its most extended configuration to investigate the innermost (within a radius of 290 R* from the star) circumstellar envelope (CSE) of IRC+10216 where acceleration of gas and dust due to strong stellar radiation is taking place. We imaged the CSE using HCN and other molecular lines with a beam size of 0.”22 x 0.”46, deeply into the very inner edge (15 R*) of the envelope where the expansion velocity is only 3 km/s. HCN maser components are spatially resolved for the first time on an astronomical object. We identified two discrete regions in the envelope: a region with a radius of 15 R*, where molecular species have just formed and the gas has begun to be accelerated (Region I) and a shell region (Region II) with a radius of 23 R* and a thickness of 15 R*, whose expansion velocity has reached up to 13 km/s, nearly the terminal velocity of 15 km/s. In Region II, the P.A. of the most copious mass loss direction was found to be $120 \pm 10$ degrees, which may correspond to the equatorial direction of the star. Region II contains a torus-like feature.
These two regions may have emerged due to significant differences in the size distributions of the dust particles in the two regions.

6.6. Millimeter wavelength molecular line observations of two extreme carbon stars CIT 6 and CRL 3068

Yong Zhang, Sun Kwok, Jun-ichi Nakashima (Department of Physics, University of Hong Kong, Pokfulam Road, Hong Kong), and Dinh-V-Trung (Institute of Astronomy and Astrophysics, Academia Sinica P.O Box 23-141, Taipei 106, Taiwan)

We present the results of a molecular survey of the two extreme C-rich envelope CIT 6 and CRL 3068 in the $\lambda$ 2 mm and 1.3 mm bands carried out with the Arizona Radio Observatory (ARO) 12 m telescope and the Heinrich Hertz Submillimeter Telescope (SMT). Several new transitions are detected for the first time. We determine the column densities and fractional abundances, and compare the results with those found for the archetypal carbon star IRC+10216 which is believed to be less evolved. Our observations provide important clues for understanding circumstellar chemistry. However, the spatial distributions of molecules in the two carbon stars are poorly known, and require further interferometer observations at high angular resolution.

7. Nearby Galaxies

7.1. 12CO(J=1-0) distribution of the Virgo spiral galaxies

E. J. Chung (Dept. of Astronomy, Yonsei University, Seoul, Korea), M.-H. Rhee (Yonsei University Observatory, Yonsei University, Seoul, Korea), and H. Kim (Korea Astronomy and Space Science Institute, Daejeon, Korea)

We have performed an On-The-Fly (OTF) mapping survey of 12CO(J=1-0) emission in 28 Virgo cluster spiral galaxies using the Five College Radio Astronomy Observatory (FCRAO) 14-m telescope. We detected CO emission in 20 galaxies with uniform sensitivity, and obtained CO maps covering the entire stellar disks for 14 galaxies. Our CO data confirms that CO is confined to the galactic center and disk in most galaxies in the Virgo cluster. However, slight asymmetric distribution and significant structures as well as kinematic disturbances are frequently shown. It appears that CO molecules are not affected by the cluster environments such as distance from the cluster center of M87. However, some galaxies (NGC 4298, NGC 4647, and NGC 4654) show a CO extension toward M87 in our results.

7.2. Warm and cold dust in blue compact dwarf galaxies

H. Hirashita (Academia Sinica Institute of Astronomy and Astrophysics, Taipei, Taiwan), H. Kaneda (Nagoya University, Nagoya, Japan), T. Onaka (University of Tokyo, Tokyo, Japan), T. Suzuki (NAOJ, Mitaka, Japan), and T. T. Ichikawa (University of Tsukuba, Tsukuba, Japan)

We observed far-infrared (FIR) dust emission from nearby blue compact dwarf galaxies (BCDs) by AKARI. BCDs generally have low metallicity, but dust extinction can be severe even in low metallicity environments if the star-forming regions are compact enough. Our analysis of AKARI data revealed high dust temperatures in BCDs, supporting compact and intense star-forming activities in BCDs. On the other hand, our theoretical calculation shows that cold dust component which should be traced in submillimeter (not in FIR) could exist. Moreover, high-resolution observations by e.g. ALMA are necessary to really trace the origin of the cold dust component. In particular, we can directly constrain dust optical depth by high-resolution observations, and dust optical depth is indeed important to test the hypothesis that the cold dust component originates from a highly shielded environment. Finally we comment on dust enrichment in metal-poor galaxies based on our theoretical framework.

7.3. Towards a more complete model for the radially-infalling molecular filaments in Per A

I-Ting Ho, Jeremy Lim, and Dinh-V-Trung (Academia Sinica Institute of Astronomy and Astrophysics, Taipei, Taiwan)

Our previous SMA CO(2-1) observations of Per
A, the cD galaxy in the Perseus cluster, at an angular resolution of 3" (1 kpc) revealed that its molecular gas within a central radius of 10 kpc is concentrated in six radial filaments distributed both east and west of center (three on each side). We successfully modeled the kinematics of the longest 'Eastern' and 'Western' filaments (which increase in blueshifted velocities with decreasing radii) as free-fall in the gravity potential of PerA, providing the most direct evidence yet for gas deposited by an X-ray cooling flow. Here, we report follow-up observations at an angular resolution of 1.5" (500pc) that better defines the kinematics of each filament. We show that the relatively short filament 'E1', which lies just beyond but is radially aligned with the 'Eastern' filament, and which we previously treated as two dynamically distinct filaments, can now be explained as a single disturbed filament. Our model assumes, as is apparently supported by the X-ray image, that a pressure wave driven by a buoyant X-ray bubble produced by the radio jet from the AGN in PerA has just passed through the 'Eastern' filament and currently lies in the gap between this filament and 'E1'. The pressure wave retards the infall motion of the 'Eastern' filament, thus producing a hook-like feature in the PV-diagram of the 'Eastern+E1' filament. Our model for this filament suggests that the radially infalling molecular gas in Per A may experience several episodes of deceleration before reaching the center.

7.4. First CO imaging of NGC1482: A unique early-type galaxy with a Superwind feedback

Ananda Hota (Academia Sinica Institute of Astronomy and Astrophysics, Taipei, Taiwan), Daniel Espada (Harvard-Smithsonian Centre for Astrophysics, 60 Garden St., Cambridge, M.A 02138), Youichi Ohyama and Satoki Matsushita (Academia Sinica Institute of Astronomy and Astrophysics, Taipei, Taiwan), Sergio Martin (Harvard-Smithsonian Centre for Astrophysics, 60 Garden St., Cambridge, M.A 02138), Kotaro Kohno (Institute of Astronomy, The University of Tokyo, 2-21-1 Osawa, Mitaka, Tokyo 181-0015), Dinh-V-Trung (Academia Sinica Institute of Astronomy and Astrophysics, Taipei, Taiwan), D.J. Saikia (National Centre for Radio Astrophysics, TIFR, Pune University Campus, Post Bag 3, Pune 411 007, India), Chanda J. Jog (Department of Physics, Indian Institute of Science, Bangalore 560012, India), Sandor Molnar (Academia Sinica Institute of Astronomy and Astrophysics, Taipei, Taiwan), Koichiro Nakanishi (Nobeyama Radio Observatory, Minamimaki, Minamisaku, Nagano 384-1805), Jeremy Lim (Academia Sinica Institute of Astronomy and Astrophysics, Taipei, Taiwan)

We present the first high resolution molecular gas imaging study using SMA, along with new panchromatic view, of the nearby galaxy NGC1482, which has a powerful M82-like starburst-driven Superwind outflow. NGC1482 is of similar size and mass as M82 but, it is likely the only early-type galaxy with a well collimated Superwind, providing unique opportunity to study wind-collimation, wind-ISM interaction and nuclear-evolution. Combining high resolution radio continuum (VLA), mid-IR (VLT) and hard x-ray (Chandra) images we suggest it to have a binary nucleus (separation 350 pc). Significant differences have been found in Spectral Energy Distribution, across hard x-ray to radio, between the nuclei, suggesting their independent history. Our HI emission (VLA) maps of two tidal tails, 58 and 65 kpc long, and its velocity field establishes NGC1482 it to be an advanced merger remnant. The central starburst region, best seen in our 5GHz radio continuum map, extending over 1 kpc, is at the base and drives the bi-conical outflow. Observing with the SMA, we have found the molecular gas counterpart to this central starburst region, rotating with the large-scale ISM and containing both the nuclei. We have observed not only 12CO but also the isotopologues 13CO and C18O (J= 2–1) We find a large amount of molecular gas in this galaxy, which is exponentially concentrated toward the center, and show a spatial and kinematically differentiable circumnuclear feature (¡500 pc). A gradient in the radial distribution of the 12CO/13CO isotopic ratios is seen, in the sense that the 12CO/13CO is lower toward the center. We will discuss the effect of the starburst, the role of possible external gas, and the interaction of the two nuclei, in order to explain such a gradient. Unlike other two lines, C18O avoids the inter-nuclei region and shows a possible cavity or molecular bubble of size 600
PC, broken along the wind axis. Molecular gas surrounding this central 1kpc region, up to 2.5kpc from centre, shows some distinct features in velocity maps and is structurally misaligned with the central edge-on starburst disk. This misaligned structure, seen as a partial ring, has corresponding faint stellar and dust emission (Spitzer), H-alpha, and compact HI emission (GMRT) blobs. Co-spatial with it, UV (GALEX) images display a striking 5kpc long prominent arc of star formation. Chaotic velocity field, deviating from simple rotation, is seen in the molecular gas possibly associated with this partial-ring/arc. Many kinematic evidences are also found for the outflow to affect the circum-nuclear ISM compressing and driving it outward. It is likely that this dense gas and dust ring collimate the Superwind outflow and/or is being eroded by it. We argue that as a first case of galactic-scale positive-feedback, Superwind has triggered young massive star formation in the molecular clouds of the expanding gas ring surrounding the centre. From our new panchromatic view of this galaxy, we discuss the origin and evolution of this intriguing system.

7.5. Study of the Dusty Cores and Filaments in the Large Magellanic Cloud

S. Kim (Astronomy and Space Science Department, Sejong University, Seoul, Republic of Korea), MEGA-SAGE Team

We present study of the characteristics of the warm dust emission in the Large Magellanic Cloud (LMC) using the Spitzer/MIPS observations of the LMC. We search for the hot dust cores and filaments in the star forming regions in the LMC and trace the dust temperature by applying a radiative transfer model. We probe temperature structures across the filaments and examine the dust clumpy structures corresponding to Jeans length. We investigate the mass spectra of dust cores and clouds and perform a direct comparison of observational results to the other studies by submm and mm dust continuum emission from the massive star forming regions.

7.6. From Near-IR to Millimeter: An Investigation of the Dust Content in the NGC1512/1510 Pair

Guilin Liu, Min S. Yun, Grant Wilson (University of Massachusetts, Amherst, MA, USA), and Bruce T. Draine (Princeton University, NJ, USA)

Central to the chemistry of interstellar gas, dust is widely known to be important for astrophysical studies of star formation activity. However, obtaining accurate determinations of dust mass have been challenging, because measurements at wavelengths shorter than 100–200 micron (accessible to IRAS, ISO, and the Spitzer Space Telescope) are sensitive to both the adopted dust mean temperature(s) and dust emissivity. (Sub-)mm radio observations probe the Rayleigh-Jeans tail of the Planck function for typical galaxy dust emission, and the inferred dust masses are therefore less sensitive to the dust temperature. These measurements also offer additional leverage for constraining, when used together with shorter wavelength infrared data, the dust temperature itself. We have combined the Spitzer imaging data on the interacting galaxy pair NGC1512/1510 with images at 1.1mm wavelength from ASTE/AzTEC to investigate the IR/mm spectral energy distribution (SED) of dust for those two galaxies, and for regions within the larger NGC1512. By deriving accurate dust masses for the two galaxies, and comparing the SEDs between sub-regions, we find a dust temperature variation from the central region to the arms of NGC1512, as well as a further evidence that a diffuse cold dust component with a remarkably uniform temperature 14–16 K exists in both galaxies, which are otherwise very different in morphology, color and metallicity. This project is to be extended into a substantial study of the dust properties of nearby star forming galaxies, and thus shed light on the processes underlying the formation of stars on galactic scales.

7.7. High resolution study of star formation activity over bars and spiral structures in NGC 4303

Rieko. Momose (Department of Astronomy, University of Tokyo, Bunkyo, Tokyo), Sachiko. K. Okumura (National Astronomical Observatory of Japan, Mitaka, Tokyo), Jin. Koda (Depart-
We present $^{12}\text{CO}(J=1-0)$ observations of barred spiral galaxy NGC 4303 including the outer spiral arms with 45 m radio telescope of Nobeyama Radio Observatory (NRO45m) and Combined Array for Research in Millimeter-wave Astronomy (CARMA). Combining NRO45m data and CARMA data enable us to archive high spacial resolution ($3.2''\times 3.2''$ sim 250 pc times 250 pc) and high sensitivity ($1\text{~sigma} \sim 34\text{~mJy beam}^{-1}$), to estimate accurate physical quantities (e.g., molecular gas mass and velocity field) and to discuss dynamics of molecular gas with GMA-scale in NGC 4303.

Comparing star formation activities depending on the bar, the nucleus and the arms, we made two maps of star formation rates (SFRs) and star formation efficiencies ($\text{SFEs} = \text{SFRs}/M_{\text{gas}}$) over the whole galaxy. As a results of area-averaged SFEs, there is little difference between the bar and the arms($1.1 \times 10^{-8}\text{ yr}^{-1}$ for the bar and $1.2 \times 10^{-8}\text{ yr}^{-1}$ for the arms), and SFEs are not so high comparing to the nucleus ($3.0 \times 10^{-8}\text{ yr}^{-1}$). However, both the bar and the arms have about one-order dispersion of SFEs within the regions.

Analysis about shear motion using the velocity gradient map estimated from the observed velocity field shows that large velocity gradients (350 km/s/kpc) appear in the nucleus and the bar region and shear motion would work around offset ridges. Moreover, the regions of higher SFEs are distributed as anti-correlated with the offset ridges. These results indicate that gravitational instability of molecular cloud leading to star formation would be suppressed by strong shear motion around offset ridges. The velocity gradient map also shows arc-like features accompanying on HII regions in the arms.

7.8. Tracing the properties of extragalactic molecular gas with ALMA

S. Mühle (Joint Institute for VLBI in Europe, The Netherlands), E.R. Seaquist (University of Toronto, Canada), C. Henkel (Max-Planck-Institut für Radioastronomie, Germany)

There is growing evidence that the properties of the molecular gas in the nuclei of starburst galaxies and nearby AGN may be very different from those seen in Galactic star forming regions. Unfortunately, among the fundamental parameters derived from molecular line observations, the kinetic temperature of the molecular gas in external galaxies is often not well constrained due to a lack of suitable tracers.

In this talk, we present a new method to determine the kinetic temperature and other physical properties of the molecular gas in extragalactic objects, which is tailored to the capabilities of ALMA. Our method uses observations of selected formaldehyde ($\text{H}_2\text{CO}$) lines and is completely independent of the dust temperature and other molecules like the Galactic standard "cloud thermometer" $\text{NH}_3$. We demonstrate the diagnostic power of the selected formaldehyde lines in deriving the properties of extragalactic molecular gas over a wide range of temperatures, gas densities and column densities per velocity interval and show examples of $\text{H}_2\text{CO}$ spectra from nearby starburst galaxies and AGN observed with the IRAM 30-m Telescope. In particular, we discuss the results of our multi-transition line study of the $\text{H}_2\text{CO}$ emission from the prototypical starburst galaxy M82. Using our non-LTE radiative transfer model, we tightly constrain the physical properties of the dense gas in the prominent molecular lobes. The results agree very well with the properties of the probably dominant molecular gas component found in the most comprehensive CO studies. In general, our method seems to be particularly sensitive to the high-excitation phase of the molecular gas, which may be the dominant phase in nearby starburst cores and AGN.

7.9. ASTE CO(3-2) On-the-fly Mapping of the Spiral Galaxy M 83: GMA Properties in the Whole Optical Disk

Kazuyuki Muraoka (Nobeyama Radio Observatory, Minamimaki, Minamisaku, Nagano 384-1305), Kotaro Kohno (Institute of Astronomy, The University of Tokyo, 2-21-1 Osawa, Mitaka, Tokyo 181-0015), Tomoka Tosaki and Nario Kuno (Nobeyama Radio Observatory, Minamimaki, Minamisaku, Nagano 384-1305), Kouichiro Nakan-
We present a new on-the-fly (OTF) mapping of CO(J = 3 – 2) line emission with the Atacama Submillimeter Telescope Experiment (ASTE) toward the 8′ × 8′ (or 10.5 × 10.5 kpc at the distance of 4.5 Mpc) region of the nearby barred spiral galaxy M 83 at an effective resolution of 25″. Due to its very high sensitivity, our CO(J = 3 – 2) map can depict not only spiral arm structures but also spur-like substructures extended in inter-arm regions. We have identified 54 CO(J = 3 – 2) clumps as Giant Molecular cloud Associations (GMAs) employing the CLUMPFIND algorithm, and have obtained their sizes, velocity dispersions, virial masses, and CO luminosity masses. We found that the virial parameter α, which is defined as the ratio of the virial mass to the CO luminosity mass, is almost unity for GMAs in spiral arms, whereas there exists some GMAs whose α are 3 – 10 in the inter-arm region. In addition, we found that GMAs with higher α tend not to be associated with massive star forming regions, while other virialized GMAs are associated with star forming regions. Since α mainly depends on velocity dispersion of the GMA, we suppose the onset of star formation in these unvirialized GMAs with higher α are suppressed by an increase of internal velocity dispersions of Giant Molecular Clouds (GMCs) within these GMAs due to shear motion.

### 7.10. Wide field molecular gas mapping observations toward NGC 253

K. Nakanishi (National Astronomical Observatory of Japan), K. Sorai (Hokkaido University), N. Nakai (Tsukuba University), K. Kohno (University of Tokyo), and N. Kuno, T. Tosaki (Nobeyama Radio Observatory)

Wide field and high spatial resolution CO molecular emission line mapping observations toward NGC 253 were performed. NGC 253 is a very nearby (D = 3.4 Mpc) and archetypal starburst galaxy. CO(1-0) and (3-2) emission line mapping observations were carried out using the Nobeyama 45-m telescope and the Atacama Submillimeter Telescope Experiment (ASTE), respectively. The maps cover about 10 × 3 arcmin (= 7.3 × 2.1 kpc) for both transitions, and the spatial resolutions are 15 arcsec (= 182 pc) and 24 arcsec (= 290 pc) for (1-0) and (3-2), respectively. The CO(3-2) map is the first large area map which includes the galactic bar, the bar-end, and the starburst (2 kpc) ring. Strong CO(3-2) emissions are detected not only at the galactic center but also at the bar-end and the starburst ring. Moderate to high (3-2)/(1-0) ratio (r31 = 0.6-1.0) areas which suggest there are large amount of dense (n(H2) > 10^3-4 cm^-3) molecular gas agree well with massive star-forming regions.

### 7.11. Dynamical Structure and Star Formation in the Barred Galaxy NGC 7552

Hsi-an Pan (Academia Sinica Institute of Astronomy and Astrophysics, Taipei, Taiwan), (Department of Earth Sciences, National Taiwan Normal University, Taipei, Taiwan), Jeremy Lim (Academia Sinica Institute of Astronomy and Astrophysics, Taipei, Taiwan), Satoki Matsushita (Academia Sinica Institute of Astronomy and Astrophysics, Taipei, Taiwan), and Tony Wang (Department of Astronomy, University of Illinois, Illinois, USA)

We infer the dynamical structure of the nearly face-on near barred galaxy NGC 7552, a member of the Grus Quartet, based on observations of its atomic and molecular gas together with an analysis of its derived rotation curve. Our HI observations with the ATCA trace the spatial-kinematic structure of the galaxy from a (projected) radius of 1 kpc, just beyond a central starburst ring, to 17 kpc. Our 12CO(2-1) and 13CO(2-1) observations with the SMA, as well as HCN(1-0) and HCO+ (1-0) observations with the ATCA, trace the spatial-kinematic structure of the inner regions of the galaxy from close to the center to a radius of 0.5 kpc, extending just beyond the starburst ring. We derived from these data a rotation curve that required the disk of the galaxy to be warped. Assuming a corotation radius coincident (as is usually assumed) with the end of the stellar bar, where a partial ring of ionized gas (seen in Hα) is visible, we then computed the locations of dynamical resonances in the galaxy. We found that the predicted radius of the outer Lindblad resonance (at 17 kpc) coincides with the outer edge...
of the observed HI emission in the disk. The predicted radius of the ultraharmonic 4:1 resonance (at 3.7 kpc) coincides with a prominent HI region in the bar. The predicted radius of the inner inner Lindblad resonance (at 0.4 kpc) coincides with a starburst ring seen in ionized (Hα) and molecular gas, as well as nonthermal radio continuum. The observed dense molecular gas as traced in HCN(1-0) and HCO+ coincides with the starburst ring. Our LVG analyses of the molecular lines indicate that the gas is not only dense, but also relatively warm (temperatures above 100 K) indicating heating from massive stars. We derived a Toomre Q parameter for the ring of 0.2, indicating that the disk is gravitationally unstable to collapse. The star-formation rate in the ring is a few solar masses per year, high than the star-formation rate in the rest of the galaxy. For comparison, the mass of molecular gas in the ring is \( \sim 1 \times 10^9 \, M_\odot \, \text{yr}^{-1} \), implying that (without further replenishment) the starburst activity in the ring (at the present star formation rate) can only last for less than a Gyr.

7.12. Molecular Disks in Southern Radio Galaxies

I. Prandoni, P. Parma, H.R. de Ruiter (INAF-IRA, Bologna, Italy), R.A. Laing, T. Wilson (ESO, Garching, Germany)

I will report on an on-going project aimed at shedding light on the fueling/accretion processes of AGNs, with particular respect to the physical conditions responsible for the triggering of radio emission in low luminosity radio galaxies. There is controversy over the fuelling mechanism in low luminosity radio galaxies. Recently it has been suggested that the accretion in such objects proceeds directly from the hot phase of the intergalactic medium, in a manner analogous to the Bondi case (Allen et al. 2006; Evans et al. 2007), rather than by a scaled-down version of orthodox disk accretion (Shakura & Sunyaev 1973). Although there is little direct evidence for either hypothesis we do know that substantial reservoirs of cold gas (detected via emission and absorption by dust, HI and CO) and some warm ionized gas are present. Dusty disks are often clearly visible (Capetti et al. 2000; Verdoes-Kleijn 1999), and in some objects (see e.g. Prandoni et al. 2007), the CO lines are double-horned, which suggests that the dusty disk and the associated cold gas are in ordered rotation around the nucleus. Interestingly, the dust mass is correlated with radio power (de Ruiter et al. 2002) and there is also a connection between the dust-lane morphology (disk/irregular) and the presence of jets, and some tendency for dust lanes and jets to be orthogonal (de Ruiter et al. 2002; Verdoes-Kleijn & de Zeeuw 2005). These associations argue that accretion of cool gas may indeed power the radio jets.

The next step is to understand the dynamics of the cool gas. Interferometric observations of the FRI radio galaxy 3C31 by Okuda et al. (2005) showed that the CO coincides spatially with the dust disk observed by HST (Martel et al. 1999) and is in ordered rotation. These authors suggest that the cool gas is in stable orbits. This is likely to be related to the low observed accretion rate and the absence of recent star formation – a picture in which small amounts of material flow inwards from the inner edge of the dust/CO disk seems likely. Detailed observations with high angular resolution and high sensitivity of this cold gas will become possible in the near future, as ALMA starts operation, and may resolve the question of fuelling in low luminosity radio galaxies, once and for all.

APEX is an excellent instrument to pre-select suitable targets for ALMA observations. We have started an observing campaign of relatively nearby radio galaxies in the Southern sky with APEX-1 at 230 GHz (CO(2 – 1)). The first three galaxies have been recently observed (summer 2008) and calibrated data have been recently made available from ESO archive. The immediate aim is to detect the CO line and study its profile. More in general this study is aimed at:

1) increasing the number of Fanaroff-Riley I radio galaxies with CO observations and thus improve our knowledge of the molecular gas masses typically found in such objects;

2) establishing whether the line profiles are always consistent with ordered rotation, or whether they are different for regular and irregular dust distributions;

3) providing targets for future interferometric follow-up, which will allow us to test the hypothesis that the cool gas is in stable orbits and search for evidence for accretion from the inner edge of the disks;
4) compare the occurrence of CO and dust, using the existing HST images.

7.13. Dense ionized gas in M82

F. Viallefond (Paris Observatory, France), W.M. Goss (NRAO, USA), and A. Pedlar (Manchester University UK)

Recombination lines at cm and mm wavelengths have been detected in several starburst galaxies. The detection of the millimeter lines indicated the presence of a plasma at high density, above 10E4 cm^{-3}, but its physical origin is uncertain, relying on models. In M82 the tight correlation in position and velocity between the mm RRL and dense molecular gas traced by HCN or HCO+ suggests that the RRL emitting sources are physically associated with dense molecular clumps. An analysis of data at 1" resolution allow us to show that these RRLs must originate not only from UCHII but also from PDRs. An analysis of data from 0.4 to 230 GHz provides constraints about the morphology of the starburst region in 3D and the base of the outflow. Although the bulk of the RRL emission is associated with neutral gas we have discovered the existence of a distinct flow which is fully ionized.

8. Galactic Center

9. AGNs, ULIRGs, and High-z Galaxies

9.1. Molecular Gas in z \leq 0.3 Palomar Green (PG) QSO Hosts

A. S. Evans (University of Virginia and NRAO, Charlottesville, Virginia, USA)

The latest results of an IRAM 30m Telescope millimeter-wave (CO) survey of z \leq 0.3 Palomar-Green (PG) QSO hosts are presented. This survey is designed to assess the fraction of PG QSO hosts with detectable amounts of star-forming molecular gas. To date, \sim 30% of the hosts have been detected in CO; these detections span the complete range of host galaxy masses, i.e., detections are not restricted to only the lower luminosity, more spiral-type host galaxies in the PG sample. This single-dish survey serves as a pre-cursor to higher resolution interferometric observations of star formation in QSO hosts to be done with the Plateau de Bure interferometer and ALMA.

9.2. Spatially Resolved Local Far-IR – HCN Correlation in Star-forming Disks

Yu GAO (Purple Mountain Observatory, Chinese Academy of Sciences, Nanjing, China)

From a survey of 65 galaxies, we have found a very strong linear relationship between HCN J=1-0 (tracer of dense molecular gas) and the far-IR luminosity for galaxies ranging over 3 orders of magnitude in L_{FIR} (Gao & Solomon 2004). This leads to a global star formation law which shows that the star formation rate (SFR) deduced from the FIR is linearly proportional to the quantity of dense molecular gas traced by HCN emission. In addition, the global HCN/CO ratio is an excellent starburst indicator. Here we present the IRAM 30m HCN J=1-0 maps in the inner disks of two face-on spirals NGC 6946 and M51. Spitzer MIPS far-IR maps of roughly comparable resolution are compared to the HCN emission. And the locally resolved FIR-HCN correlation or a local star formation law in terms of dense molecular gas is established across the inner disks of normal spiral galaxies.

9.3. AzTEC/ASTE 1.1-mm survey of the AKARI Deep Field South


Submillimeter Galaxies (SMGs) are dusty, massively star forming galaxies (star formation rates 100-1000 Msun/yr) at the early universe, and thought to be progenitors of present massive ellipticals. It is said that these massive galaxies form at dense regions of dark matter, and therefore observations of SMGs provide us with the information on the formation of large-scale struc-
ture. We report on a deep blank field survey of the AKARI Deep Field-South (ADF-S) at 1.1 mm using AzTEC camera, a 144-element bolometer mounted on the ASTE telescope at Atacama, Chile. The ADF-S is known to be a low-cirrus region which is advantageous for deep observations of distant dusty universe at far-IR wavelengths. We covered 700 arcmin$^2$ with an rms noise of 0.5-0.7 mJy/beam and detected 100 sources (>3.5 sigma). This survey exceeds the previous large mm/submm surveys in survey area, number of sources, and source reliability. Most of the AzTEC sources are not detected with AKARI FIR bands (50-180), suggesting that they are possibly at $z > 1$, considering the detection limits. The SMG number counts of ADF-S are less than those of GOODS-N and COSMOS fields and we can see a variety in number counts among 'blank fields'. We present the properties of these AzTEC sources (number counts, clustering, and other-wavelength data).

9.4. Probing the Coevolution of Galaxies and Black Holes

Luis C. Ho (Carnegie Observatories)

I will describe the use of radio observations to probe the gas content and kinematics of AGN host galaxies, and how this information can be used to constrain the properties of the host and the joint evolution of galaxies and their central supermassive black holes.

9.5. Science results from AMiBA

Chih-Wei Locutus Huang and Jian-Huei Proty Wu (Department of Physics, Institute of Astrophysics, & Center for Theoretical Sciences, National Taiwan University, Taipei 10617, Taiwan), Paul T. P. Ho (Institute of Astronomy and Astrophysics, Academia Sinica, P. O. Box 23-141, Taipei 10617, Taiwan), Kai-Yang Lin (Department of Physics, Institute of Astrophysics, & Center for Theoretical Sciences, National Taiwan University, Taipei 10617, Taiwan), and Derek Kubo and Chao-Te Li (Institute of Astronomy and Astrophysics, Academia Sinica, P. O. Box 23-141, Taipei 10617, Taiwan) ¡the abstract will be sent to Sheng-Yuan.

9.6. Comparing the CO(3-2) Sizes and Luminosities of Local and High-z Luminous Infrared Galaxies

D. Iono et al. (NAOJ)
We present a detailed comparison of the CO (3–2) emitting molecular gas between a local sample of luminous infrared galaxies (U/LIRGs) and a high-redshift sample that comprises submm selected galaxies (SMGs), quasars, and Lyman Break Galaxies (LBGs). The U/LIRG sample consists of our recent CO (3–2) survey using the Submillimeter Array while the CO (3–2) data for the high-redshift population are obtained from the literature. We find that the LCO(32) and LFIR relation is correlated over five orders of magnitude, which suggests that the molecular gas traced in CO (3–2) emission is a robust tracer of dusty star formation activity. The near unity slope of 0.93 ± 0.03 obtained from a fit to this relation suggests that the star formation efficiency is constant to within a factor of 2 across different types of galaxies residing in vastly different epochs. The CO (3–2) size measurements suggest that the molecular gas disks in local U/LIRGs (0.3–3.1 kpc) are much more compact than the SMGs (3–16 kpc), and that the size scales of SMGs are comparable to the nuclear separation (5–40 kpc) of the widely separated nuclei of U/LIRGs in our sample. We argue from these results that the SMGs studied here are predominantly intermediate stage mergers, and that the wider line widths arise from the violent merger of two massive gas-rich galaxies taking place deep in a massive halo potential.

9.7. The Coevolution of Black Holes and Host Galaxies in Nearby Type I AGNs

Minjin Kim (Carnegie Observatories, USA & Seoul National University, Korea), L. C. Ho (Carnegie Observatories, USA), M. Im (Seoul National University, Korea), C. Y. Peng (Dominion Astrophysical Observatory, Canada), and A. J. Barth (University of California - Irvine, USA)


Thomas P. Krichbaum and Anton J. Zensus (Max-Planck-Institut für Radioastronomie, Bonn, Germany)

Very Long Baseline Interferometry performed at short millimeter wavelengths is a powerful observing method to study and directly image - with micro-arcsecond scale resolution - the very central regions in the Nuclei of Galaxies. With a spatial resolution corresponding to a few to a few ten Schwarzschild radii, future mm- and sub-mm VLBI can reach the immediate vicinity of nearby super-massive black holes, such as the galactic center (Sgr A*) and M87. The participation of the major mm-/sub-mm observatories (such as e.g. the SMA, CARMA, ALMA, ...) in mm-VLBI will provide fascinating possibilities to study astrophysical effects of General Relativity in the presence of strong gravitational fields, and should help to better understand the origin of the radio luminosity and the launching mechanisms of the powerful jets in AGN.

9.9. Bright Quasars at Low Galactic Latitude and Its Applications to Millimeter/Submillimeter Astronomy

Induk Lee and Myungshin Im (Center for the Exploration of the Origin of the Universe (CEOU), Astronomy Program, Department of Physics and Astronomy, Seoul National University, Korea)

We introduce Seoul National University Bright Quasar Survey in Optical (SNUQSO), and present the result of the second phase, the main part of the survey. We also suggest their applications to millimeter/submillimeter astronomy. In the second phase, we discovered 171 new bright QSOs/AGNs that are in 0.05 < z < 0.4 at low Galactic latitude (|b| < 20°) so far. Among 171 QSOs/AGNs, 104 (60.8%) are radio sources. It was difficult to find QSOs/AGNs at the low Galactic latitude because of severe stellar contamination and extremely high Galactic extinction. For this reason, traditionally, the low Galactic latitude has been known as zone of avoidance, and QSOs/AGNs have been searched at high Galactic latitude. In order to perform the survey at the zone of avoidance, we have made a new algorithm to select QSOs/AGNs candidates, using optical (USNO B1.0), NIR (2MASS), X-ray (ROSAT), radio (NVSS and SUMSS) information. The observation were carried out using the 1.8m telescope at the Bohyun Optical Astronomy Observatory (BOAO), the 2.1m telescope at the Kitt Peak National Observatory (KPNO), and the
1.8m telescope at the IUCAA Girawali Observatory for the Northern hemisphere, and the 1.5m telescope at the Cerro Tololo Inter-American Observatory (CTIO) for the Southern hemisphere, during 2006-2008. These 104 QSOs/AGNs that are visible in radio will be useful for millimeter/submillimeter astronomical applications, such as (i) use as reference points for astrometry at the low Galactic latitude; (ii) studying jets and molecular gas content and star formation activity of their host galaxies. This work was supported by the Korea Science and Engineering Foundation (KOSEF) grant No. 2009-0063616, funded by the Korea government (MEST).

9.10. Molecular Gas deposited by an X-Ray Cooling Flow in the Perseus Cluster

Jeremy Lim (Academia Sinica Institute of Astronomy and Astrophysics, Taipei, Taiwan), Ho I-Ting (National Taiwan University, Taiwan), and Dinh-V-Trung (Academia Sinica Institute of Astronomy and Astrophysics, Taipei, Taiwan)

Over 30 years ago, it was recognized that the hot X-ray-emitting gas in which galaxy clusters are immersed should (in relaxed clusters where the X-ray gas is nearly in hydrostatic equilibrium) cool rapidly at the cluster center thus producing an X-ray cooling flow. Observations this decade, however, show that the X-ray gas around the cluster center is strongly disturbed (and presumably reheated) by the AGN in the cD galaxy, thus mitigating if not quenching the cooling flow. Nevertheless, many cD galaxies in putative cooling-flow clusters are known to contain relatively large amounts of relatively cool gas (up to $\sim10^{11}\ M_\odot$), the dominant component of which (when detectable) is in the form of cool molecular gas traced in CO. Is this relatively cool gas deposited by a X-ray cooling flow, or is it acquired through mergers with gas-rich galaxies? Here, I report our SMA observations of CO(2-1) in Perseus A, which is the central dominant elliptical galaxy in the Perseus Cluster (the X-ray-brightest cluster in the sky). I show that the spatial-kinematic distribution of the cool molecular gas in Perseus A is not consistent with this gas being accreted from a merger but instead consistent with this gas being deposited by an X-ray cooling flow, thus providing the most direct evidence yet for a X-ray cooling flow in any cluster. I describe the relationship between the cool molecular gas and other gas components at higher temperatures, and examine the possible fate of this gas in both fueling star formation and the AGN in Perseus A.

9.11. Where is Obscuring Torus? — 10 pc Resolution Imaging of Molecular Gas around the Seyfert 2 Nucleus of M51 —

S. Matsushita and J. Lim (Academia Sinica Institute of Astronomy and Astrophysics, Taipei, Taiwan), and S. Muller (Onsala Space Observatory, Onsala, Sweden)

Previous molecular gas observations at arcsecond-scale resolution of the Seyfert 2 galaxy M51 suggest the presence of a dense circumnuclear rotating disk, which may be the reservoir for fueling the AGN and obscures it from direct view. However, our SMA CO(3-2) observations show a hint of a velocity gradient perpendicular to the rotating disk, which suggests a more complex structure than previously thought. We carried out PdBI CO(2-1) observations, yielding to spatial resolution lower than 15 pc. The images show no clear evidence of disk structure as suggested by previous observations. The emission at the western side of the nucleus shows an elongated structure along the radio jet, and likely originates from gas entrained by the jet. The emission at the eastern side of the nucleus is elongated toward the nucleus, and shows a velocity gradient blueshifted toward it, which is an opposite sense as the results observed with larger beam. Possible explanations for the observed distribution and kinematics of the nuclear molecular gas are that a rotating gas disk disturbed by the jet, a streaming gas toward the nucleus, or the disk with another smaller conter-or Keplarian-rotating gas disk inside.

9.12. The Origins of the Cosmic Millimeter Background

Kyle Penner (Univ. of Arizona)

To be submitted
9.13. X-ray and Optical spectral characteristics for the OPTX Sample of AGN

L. Trouille and A. J. Barger (University of Wisconsin - Madison), L. L. Cowie (University of Hawaii - Institute for Astronomy), R. Mushotzky (NASA Goddard Space Flight Center), Y. Yang (University of Illinois)

Using a uniformly selected and highly spectroscopically complete sample of Chandra X-ray sources, we show that one cannot use X-ray spectral classifications and optical spectral classifications equivalently. We also show that there is not a one-to-one correspondence between X-ray spectral type and the neutral hydrogen opacity of the source. We discuss our results in the context of modifications to the simple unified model for AGNs and the relationship between photon index and accretion rate.

10. Astrochemistry

10.1. The Cologne Database for Molecular Spectroscopy, CDMS, a link between laboratory spectroscopy and astronomy at high angular resolution

Holger S. P. Müller, Jürgen Stutzki, Stephan Schlemmer (I. Physikalisches Institut, Universität zu Köln, Zülpicher Str. 77, 50937 Köln, Germany)

The CDMS provides in its catalog section atomic and molecular line lists for species that have been or may be observed in space by radio astronomical means. The line list of each molecule is gathered in an individual entry; minor isotopologs have separate entries, and the same applies to excited vibrational states with the exception of some diatomic molecules. With 5 to 10 new or updated entries each month, the CDMS catalog has been growing rapidly over the past 10 years: since February 2009, there have been more than 500 entries in the CDMS — with many more entries to be created. Entries are generated from fitting (mostly) laboratory data to accepted Hamiltonian models. Despite many dedicated laboratory spectroscopic investigations in recent years, accurate data is still lacking frequently — in particular at higher frequencies, for minor isotopic species, for excited vibrational states, or for somewhat larger molecules. Using recent results, we will show that these issues are already important for single dish observations and even more so for ALMA or other radiotelescope arrays.

The main features of the CDMS catalog will be described, including recent developments concerning new entries as well as available and planned features. Attention will be given to laboratory spectroscopic needs for telescope arrays such as ALMA, the EVLA, and the SMA both, in terms of general aspects and in terms of specific examples. Selected contributions from the Cologne spectroscopy laboratories to address these needs will be presented.

10.2. The Laboratory Rotational Spectrum of iso-Propyl Cyanide and an Astronomical Search in Sagittarius B2(N)

Holger S. P. Müller (I. Physikalisches Institut, Universität zu Köln, 50937 Köln; and Max-Planck-Institut für Radioastronomie, 53121 Bonn, Germany), A. Coutens, A. Walters (CESR, Université de Toulouse (UPS), and CNRS, 31028 Toulouse, France), J.-U. Grabow (Institut für Physikalische Chemie und Elektrochemie, Lehrgebiet A, Universität Hannover, 30167 Hannover, Germany), A. Belloche, K. M. Menten (Max-Planck-Institut für Radioastronomie, 53121 Bonn, Germany), S. Schlemmer (I. Physikalisches Institut, Universität zu Köln, 50937 Köln, Germany)

We have carried out a molecular line survey of Sagittarius B2(N) in the 3 mm region with additional selected recordings at 2 and 1.3 mm to probe the chemical complexity in massive star-forming regions. Noteworthy results include the detection of aminoacetonitrile, a possible pre-

3web-page: http://www.astro.uni-koeln.de/cdms/.
cursor of the aminoacid glycine, the detection of $^{13}$C isotopologs of vinyl cyanide,\textsuperscript{5} and the detection of ethyl formate as well as normal-propyl cyanide.\textsuperscript{6} The heavy atoms in the latter molecule form a chain. An isomer with a branched structure, iso-propyl cyanide, also exists, but its rotational spectrum had been recorded only in few transitions up to 40 GHz.\textsuperscript{7} Therefore, laboratory measurements were extended. Measurements in Köln were carried out in selected regions between 40 and 600 GHz. The molecule possesses a strong $\alpha$-dipole moment component and a smaller $\epsilon$-component.\textsuperscript{8} Since the $\epsilon$-type transitions appeared to be weaker than predicted additional Stark (and also zero-field) measurements have been carried out in Hannover between 6 and 20 GHz. We will present results of these laboratory spectroscopic investigations as well as the outcome of a search for the molecule in our Sgr B2(N) line survey.

The ratio of the two isomers, even a sufficiently low upper limit for iso-propyl cyanide, should provide important clues on the interstellar chemistry leading to complex molecules.

\textsuperscript{a} A. Belloche, K. M. Menten, C. Comito, H. S. P. Müller, P. Schilke, J. Ott, S. Thorwirth, C. Hieret, 

10.3. Chemical Structure of Young Stellar Outflows

\textit{H. Nomura (Department of Astronomy, Kyoto University, Kyoto, Japan), and T.J. Millar (ARC, Queen’s University Belfast, Belfast, UK)}

It is observationally known that outflows are associated with many young stars. Observations and Theory have suggested that these outflows originate from accretion disks around the stars. Meanwhile, molecular line observations have shown that some molecules such as CH$_3$OH and SiO, which originate from icy mantle evaporation or dust sputtering, are very abundant at shocks and/or clumps in outflows.

In this work we have constructed chemical models of young stellar outflows by calculating time-dependent gas-phase chemical reactions, which are initiated by icy mantle evaporation, inside the disks and along the outflows. As a result, the molecules are dissociated into atoms at hot (>3000K) inner region of the disk where the launching velocity of the outflow could reach as high as more than 100 km/s. At the outer disk, where the gas temperature is lower (<2000K), molecular gas is launched into the outflow. Some molecules, such as CH$_3$OH, H$_2$CO, and H$_2$S, are dissociated at a shock front in the outflow if the shock speed is high enough (more than 40 km/s when the pre-shock density is 10$^5$ cm$^{-3}$). Our results suggest that detailed analysis of the molecular abundances together with outflow velocities will give us information on the structure of the outflow’s launching point in the disk or of the shock front in the outflow.

10.4. The distribution of deuterated molecules in the Orion Bar PDR

\textit{B. Parise (Max-Planck-Institut fuer Radioastronomie, Bonn, Germany)}

We present single-dish and interferometric observations of deuterated molecules towards the Orion Bar photodissociation region. The DCN molecule is found to trace molecular clumps, whose temperatures are $\sim$ 40K, located behind the ionisation front. We aim at studying in detail the chemistry at work in this PDR, to understand how deuterated molecules, usually characteristic of cold chemistry, can survive in this environment.

10.5. Chemo-dynamical models of protoplanetary disks

\textit{Dmitry Semenov (MPIA Heidelberg, Germany), Dmitry Wiebe (Institute of Astronomy of RAS, Moscow, Russia), and Thomas Henning (MPIA Heidelberg, Germany)}

The importance of turbulent transport for the chemical evolution of protoplanetary disks will be highlighted. A T Tauri disk is modeled with the alpha-model in 1+1D and used to calculate chem-
istry with a set of gas-grain and surface reactions over 5 Myr. It is shown that dynamical processes result in richer chemical complexity of protoplanetary disks compared to the static models.

10.6. New Line Survey Project with the Nobeyama 45 m Telescope


Line surveys are of fundamental importance in astronomy not only for complete understanding of chemical compositions in representative sources, but also for finding out new observing tools probing interstellar medium and star formation. We started a new line survey project in Dec. 2007. It takes about four years to complete the project. Now we are continuing observations for the second year. In the first year of the project many interesting results were obtained. The target sources are the low-mass star forming region in L1527, the shocked region in L1157, the infrared dark clouds G28.37+00.07, and the extragalaxies Arp 220, NGC 1068, and NGC 253. With the new 3 mm receivers installed on the 45 m telescope (Nakajima et al. 2008), the frequency range from 84 GHz to 115 GHz can be surveyed with much higher sensitivity than the previous observations with the old receiver. The results from the survey will be used for detailed studies on chemistry in each source, and will also provide us with useful templates for planning the observing strategy with ALMA. The preliminary results of the first year are as follows.

(1) Low-mass star-forming region L1527: L1527 is a very interesting object, because the abundances of carbon-chain molecules are high, though this source is a low-mass star forming region (Sakai et al. 2008). We detected many lines including high excitation lines of HC$_3$N (e.g. J=41-40, upper state energy of 110 K), isotopic species (D, $^{13}$C) of some carbon-chain molecules, and HCO.

(2) Prominent shocked region L1157: In L1157, where interactions between an outflow and ambient clouds are prominent (Umemoto et al. 1992 and Mikami et al. 1992), we detected many lines including C$^{34}$S, CH$_3$CHO, and HCOOCH$_3$. To study shock chemistry and gas-grain interaction, these detections are rather important information. After our observations, we noticed that HCOOCH$_3$ is independently detected with the IRAM 30 m telescope (Arce et al. 2008).

(3) Infrared dark clouds IRDCG28.37+00.07 (possible high-mass star forming regions): In G28 three interesting positions called mm1, mm4, and mm9 were selected, and shallow surveys were done. Toward mm1 and mm4 line wings were found in HCO$^+$, HCN, SiO, CS, and CH$_3$OH. These wings indicate outflow activities. In addition, CH$_3$CHO is detected only in mm1 and mm4. This molecule is one of the probable grain related species. Therefore CH$_3$CHO may be evaporated from grain. Based on these results, mm1 and mm4 are thought to be high-mass protostellar objects.

(4) External galaxies Arp 220 with ultraluminous infrared radiation, NGC 1068 with X-ray radiation from AGN, and NGC 253 with a prototypical starburst: We observed only Arp 220 in the first year, where wide absorption lines of ammonia have been detected (Takano et al. 2005). We expected such absorption lines for other molecules. We tried to find HNCO (21.98 GHz) and SO (30.00 GHz) without success at the rms noise of 1.0 and 1.5 mK, respectively. In the second year we do not observe Arp 220. We survey lines toward NGC 1068 and NGC 253 as a feasibility test. By comparing NGC 1068 and NGC 253, effective lines for probing XDR regions may be obtained.

10.7. **A Unified Monte Carlo Treatment of Gas-Grain Chemistry for Large Reaction Networks: Testing Validity of (Modified) Rate Equations.**

A.I. Vasyunin (Max Planck Institute for Astronomy, Königstuhl 17, D-69117 Heidelberg, Germany), R.T. Garrod (Department of Astronomy, Cornell University, Ithaca, NY 14853-6801, USA), D.A. Semenov (Max Planck Institute for Astronomy, Königstuhl 17, D-69117 Heidelberg, Germany), D.S. Wiebe (Institute of Astronomy of the Russian Academy of Sciences, Pyatnitskaya str. 48, 119017 Moscow, Russia), and Th. Henning (Max Planck Institute for Astronomy, Königstuhl 17, D-69117 Heidelberg, Germany)

We use the Monte Carlo technique along with the standard and modified rate equation methods to model gas-grain chemistry in dense and translucent molecular clouds. Our goal is to specify under which conditions the use of the stochastic approach is mandatory.

For the first time unified Monte Carlo approach is utilized to simulate the time-dependent gas-grain chemical evolution of the interstellar medium over a timescale of 1 Myr. The model involves about 6000 gas-phase and 200 grain surface reactions. Two cases are considered: (1) the surface mobility of all species is due to thermal hopping, (2) in addition to thermal hopping, temperature-independent quantum tunneling for H and H\(_2\) is allowed.

We found that stochastic effects are in general important for the chemical evolution of molecular clouds except for the model without tunneling and high binding energies. Classical rate equations fail to reproduce surface chemistry in this case (Vasyunin, A. I., Semenov, D. A., Wiebe, D. S., and Henning, T. 2009, ApJ, 691, 1459). At 10 K gaseous and, in particular, surface abundances of many important molecules are not much affected by stochastic processes. At higher temperatures discrepancy between stochastic and deterministic models increases. At 30 K gas-phase abundances of H\(_2\)O, NH\(_3\), and CO in the stochastic model differ from those in the deterministic model by more than an order of magnitude. Modifications to rate equations, proposed by various authors and intended to account for stochasticity of surface chemistry, while in general improving the agreement, in some cases still produce results which are even less consistent with the ‘exact’ model that conventional rate equations.

We compare the results of the unified Monte Carlo chemical model with the new modified rate equations method proposed by Garrod (2008, A&A, 491, 239) under interstellar conditions, using the same set of gas-phase and surface reactions. In most part of the explored parameter space new approximate method represents the results of the exact approach very well.

10.8. **Submillimeter high resolution spectral-line observations of Orion KL**

Kuo-Song Wang (Institute of Astronomy and Astrophysics, Academia Sinica, Taipei, Taiwan), Yi-Jehng Kuan (Department of Earth Sciences, National Taiwan Normal University, Taipei, Taiwan), Sheng-Yuan Liu (Institute of Astronomy and Astrophysics, Academia Sinica, Taipei, Taiwan), and Steven B. Charnley (Astrochemistry Laboratory & Center for Astrobiology, Solar System Exploration Division, NASA Goddard Space Flight Center, Greenbelt, USA)

Orion KL is one of the primary target for study the massive star formation in our galaxy due to its proximity (~450 pc). Especially, the hot core chemistry therein including the nitrogen/oxygen dichotomy between the Orion Hot Core and Compact Ridge attracts lots of attention in the past few decades. Several chemical models were proposed to uncover the mystery of hot core chemistry based on mainly the single-dish spectral line surveys; however, the whole picture is not complete yet. One of the main reasons is the lack of high-resolution observations. As a consequence, we conducted arcsec-resolution Submillimeter Array observations toward the Orion KL hot molecular core at 331 and 341 GHz. Multi-transitions of CH\(_3\)CN, C\(_2\)H\(_4\)CN, C\(_2\)H\(_5\)CN, CH\(_3\)OH and HCOOCH\(_3\) are imaged. With the ”population diagram” analysis, kinetic temperature distribution of Orion KL is derived together with the small scale (~500 AU) variations of chemical abundances. In addition, clumpy structures are also unveiled both in the spatial and spectral domains. Our results would be supportive for future chemical modeling and as the basis of coming
ALMA observations.

10.9. Herschel/HIFI observations of EXtra-Ordinary Sources—The Orion and SgrB2 Molecular Clouds: A Guaranteed Time Key Program Proposal

E.A. Bergin, S. Wang et al. (U. of Michigan)

As a GT Key Program we propose to perform full HIFI line surveys of 5 sources in the giant molecular clouds Orion and Sagittarius B2. These extraordinary star-forming regions contain the best studied examples of physical and chemical processes prevalent in the interstellar medium, including gravitational compression, thermal and turbulent pressure support, photodissociation, gas and grain chemistry in dense and diffuse quiescent gas, and shocks. With high excitation, rich chemistry, and large H$_2$ column, they give the highest chance for new detections in a sensitive search for new molecules. Line Surveys of sources (Orion KL, Orion S, Orion Bar, Sgr B2 N+M) defined by these phenomena form the backbone of this proposed program. The HIFI line surveys will be supplemented by deeper line searches, water maps, and, in at least 3 sources, full spectrum PACS scans.

Herschel offers unprecedented sensitivity and relative calibration accuracy, as well as continuous spectral coverage across the gaps imposed by the atmosphere, opening up a largely unexplored wavelength regime to high resolution spectroscopy. These data will take line surveys to a new level and we will use them to comprehensively characterize the physics (density, thermal balance, kinematics, radiation field) and chemistry (chemical assay, ionization, deuterium fractionation, water ortho/para ratio) of star-forming molecular gas in a manner not previously possible. The opening of this spectral range is also an opportunity to detect the bending transitions of carbon chains and polycyclic aromatic hydrocarbons, along with the rotational transitions of complex organics.

11. Instrumentation

11.1. A prototype receiver for ALMA Band 1 (31-45 GHz)

L. Bronfman and J. May (Astronomy Department, Universidad de Chile), and N. Reyes, P. Zorzi, and P. Mena, (Electrical Engineering Department, Universidad de Chile)

In 2008 we started a program to develop a prototype for the ALMA Band 1 receiver (31-45 GHz). We will report on the progress of such program and, in particular, of the new laboratory setup and the design of the front end, the optics, and the OMT.

11.2. ALMA Band 1 (31-45 GHz) Receiver Development at HIA

Stéphane Claude, Frank Jiang, David Dousset, Nathan Wren, Ivan Wevers, Murray Fletcher and Doug Henke. (Herzberg Institute of Astrophysics, National Research Council of Canada, Victoria, BC, V9E 2E7, Canada http://www.hia-iaha.nrc-cnrc.gc.ca/), Ke Wu (Poly-Grames Research Center, Department of Electrical Engineering, Ecole Polytechnique de Montreal, Montreal, QC, Canada H3T 1J4 Canada)

This poster presents the progress of the HIA team towards the development of a Band 1 receiver. A conceptual design was started by the ALMA project but the design has not evolved as other high priority bands had to be design and fabricated. In order to move forward in the detailed design of Band 1, key components that need special attention are optics, orthomode transducer (OMT), low noise amplifier (LNA) and mixer. We will highlight systems issues through a systems analysis such as noise and optics alignment. Prototype performance of a cryogenic LNA and an OMT specifically designed for the Band 1 will be presented.

11.3. Phase transference between 220 and 660 GHz in GGD27 with the SMA

M. Fernandez-Lopez and S. Curiel (Instituto de Astronomia, UNAM, Mexico City, Mexico.), J.M. Girart (Institut de Ciencies de l’Espai (CSIC-IEEC), Barcelona, Spain.), N. Patel (Harvard-Smithsonian CfA, Cambridge, USA.), and Y. Gomez (CRYA, UNAM, Morelia, Mexico.)

Atmospheric variations, mainly caused by water vapor at mm/submm wavelengths, change the
path length of electromagnetic waves, thus limiting angular resolution and sensitivity of interferometers. The standard method of phase calibration works with strong calibrators not far away from the target source, which becomes a great problem at high frequencies. The SMA interferometer can observe two separated frequencies simultaneously enabling the possibility of a phase transference between both bands. Theoretically, the behavior of the phase at 660 GHz mimics that of the phase at 220 GHz, with the only difference of a scale factor. We have successfully carried out a phase transference between these two bands with the SMA and compared it with a phase referencing calibration. Here, we will describe both technics and we will compare the results obtained.

11.4. MUSTANG: A 3mm High Resolution Single Dish Continuum Camera for the 100m GBT


MUSTANG, the Multiplexed SQUID TES Array at Ninety GHz, is an 8 by 8 array of TES bolometers designed as a user instrument for the 100 m diameter Green Bank radio telescope (GBT). MUSTANG is the GBT’s first 90 GHz instrument and its first focal plane array. As a continuum receiver on a large single dish, MUSTANG offers a unique combination of 8 arcsecond angular resolution and high sensitivity to extended structure. Over the last season, improvements made to the receivers re-imaging optics and advances in precision control of the GBTs active surface have increased the instruments sensitivity dramatically. MUSTANG is currently available to the astronomical community through the general NRAO proposal system. A wide range of preliminary science has already been accomplished including high resolution maps of AGN, Class 0 Protostars, HII regions, Molecular Clouds and the Sunyaev Zeldovich effect in galaxy clusters.

11.5. High Resolution Imaging with CARMA using the Paired Antenna Calibration System (PACS)

Laura M. Pérez (Department of Astronomy, California Institute of Technology, Pasadena, CA, USA), J. W. Lamb, D. P. Woody, D.C.-J. Bock (Owens Valley Radio Observatory, California Institute of Technology, Big Pine, CA, USA), B. A. Zauderer, P. J. Teuben (Department of Astronomy, University of Maryland, College Park, MD, USA), J. M. Carpenter (Department of Astronomy, California Institute of Technology, Pasadena, CA, USA), E. M. Leitch, D. P. Marrone, T. L. Calverhouse (Department of Astronomy and Astrophysics, University of Chicago, Chicago, IL, USA), S. Muchovej (Owens Valley Radio Observatory, California Institute of Technology, Big Pine, CA, USA), and M. C. H. Wright, R. L. Plambeck (Department of Astronomy, University of California, Berkeley, Berkeley, CA, USA)

High resolution imaging at millimeter wavelengths is essential to understand a variety of phenomena, from circumstellar disks to high redshift galaxies. At CARMA, the atmospheric transparency is excellent for a large fraction of the year, but the ability to obtain high resolution images in the longest A- and B configurations (up to 2 km baselines, 0.15” resolution) is limited by atmospheric scintillation, which can cause large phase errors over the long baselines required for these studies. CARMA has been testing a new technique, the Paired Antenna Calibration System (PACS), to ensure routine phase correction of the rapidly varying atmospheric delay. PACS pairs the Sunyaev-Zeldovich Array (SZA) 3.5-m antennas with selected CARMA 6.1-m and 10.4-m antennas offset by 25 - 30m. The SZA antennas observe a quasar at 30 GHz, which is a few degrees from the science target observed by CARMA. The correction process takes place after the data is collected, and the atmospheric delay measured at 30 GHz can be scaled up to 100 or 230 GHz because the dispersion in delay is minimal and ionospheric scintillation is negligible. We describe the technique and present observational results using PACS during A and B-array configurations, between Nov 2008 and February 2009, that achieve the highest spatial resolution currently possible.
11.6. The Extended Submillimeter Array (eSMA)

R.P.J. Tilanus (Joint Astronomy Centre, Hawaii / Netherlands Organisation for Scientific Research), eSMA commissioning team

The eSMA combines the SMA, JCMT, and CSO into a single sub-mm interferometer with approximately twice the collecting area of the SMA and a 1.5x longer maximum baseline. Until ALMA early science observing, the eSMA will be the facility capable of the highest angular resolution observations at 345 GHz. The eSMA will operate on a part-time basis and in the 345 GHz window taking full advantage of Mauna Kea’s excellent observing conditions and prolonged periods of superb weather at that frequency. The commissioning of the eSMA is nearing completion and in presentation I will give a summary its capabilities and discuss its current status. In addition I will show results from science verification observations at 230 GHz from last year as well as more recent results at 345 GHz.

The eSMA infra-structure has also been exploited in mm-VLBI observations with the SMT in Arizona and CARMA antennas in California of SgrA* and M87. Successful observations in 2007 resulted in a detection of SgrA* on the Mauna Kea - Arizona baseline (resolution 60 micro-arcsecs), but only used the JCMT. I will briefly discuss new mm-VLBI observations from this spring that successfully phased up eSMA antennas into the equivalent of 20m single-dish on Mauna Kea.

11.7. Current and future polarimetric capabilities of the IRAM Plateau de Bure Interferometer

S. Trippe (Institut de Radioastronomie Millimétrique, Grenoble, France)

In the near future, the IRAM PdBI is going to be equipped with polarimetric capabilities. Additionally, there are studies on polarized calibration sources currently ongoing. I will give an overview on these current and future projects and present a few potential science cases.

11.8. The relocation of KOSMA submillimeter telescope: from Gornergrat Alps to Yangbajing Tibet plateau

Jun-Jie Wang (National Astronomical Observatories, Chinese Academy of Sciences, Beijing, China)

The KOSMA submillimeter telescope (diameter 3 m) has been scheduled, by National Astronomical Observatories of CAS and Cologne University of Germany, to move from Gornergrat (altitude 3200 m) of Switzerland to Yangbajing (altitude 4300 m) of Tibet, China, where the observational condition for submm is better. Meanwhile, a study of the relevant scientific objectives will be carried out. And the test observations will also be made after the telescope is installed in the second half year of 2010. If the project can complete successfully, there will be the first submm telescope that can be provided to astronomers to make regular observations in China. Yangbajing Submm Astronomical Observatory will also be one of the highest astronomical sites in the northern hemisphere.