P35

Three-dimensional Modelling of the Emission of Clumpy PDRs

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The interstellar medium (ISM) is permanently irradiated and heated by the UV contribution of massive stars to the interstellar radiation field. A photon dominated region (PDR) is a region in interstellar space where the interstellar farUV radiation (with photon energies 6 eV$< h\nu <$13.6 eV) dominates the energy balance and the chemistry of the ISM. It is under investigation whether the radiation field triggers star formation in the ISM.
The KOSMA-τ PDR model has been developed to simulate the line emission of spherical geometries, ”clumps”, in the ISM. Furthermore it has been shown that an equivalent superposition of such clumps (clumpy ensemble) can be used to mimic the structure of the ISM.
Here, a 3-dimensional model has been set up, which not only can be used to simulate the emission of clumpy PDRs in arbitrary geometric setups, but it can also predict full line profiles. By assembling a 3-dimensional compound from different clumpy ensembles this model facilitates modelling and analysis of the spatial structure of star forming regions. It can simulate the variation of parameters like the UV field strength or the local density for the different clumpy ensembles within one star forming region. The calculation of the radiative transport through the compound facilitates the comparison to observational maps.
As a first example the new model is used to simulate the main cooling lines and other diagnostics of the Orion Bar. Through the fit of the observational data we are able to constrain the spatial variation of the PDR parameters such as the total mass, the radial dependence of the density, the ambient UV field strength, and the clump size cutoffs. Future observations with high spatial resolution are required to further diminish uncertainties in the model outcome. Therefore ALMA will provide us with the data that is needed to enhance our understanding of star formation processes in galaxies.

P36

Simulated ALMA observations of first Larson cores in collapsing low-mass dense cores

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Although predicted by theoretical models, the existence of first hydrostatic cores has yet to be convincingly demonstrated by (sub)millimetre observations. The multiplicity at this early stage of the star formation process is poorly constrained.

We present predictions of ALMA dust continuum emission maps from early Class 0 objects and demonstrate how ALMA will be able to give a clear, if not final, answer to the fragmentation crisis in these objects. Following previous work (Commerçon et al. 2012), we post-process three state-of-the-art radiation-magneto-hydrodynamic 3D adaptive mesh refinement calculations of first hydrostatic core models performed with the `RAMSES` code. We compute the dust thermal continuum emission with the 3D radiative transfer code `RADMC-3D`, then produce synthetic ALMA observations using the simulator included in the `GILDAS` software package.

We analyze the results given by the different bands and array configurations and identify which combinations of the two represent our best chance of observing the first hydrostatic cores. We also show that such observations will help in identifying the physical processes occurring within collapsing dense cores. If the magnetic field is playing a role, the emission pattern will show evidence of a pseudo-disk and even of a magnetically driven outflow, which pure hydrodynamical calculations cannot reproduce.

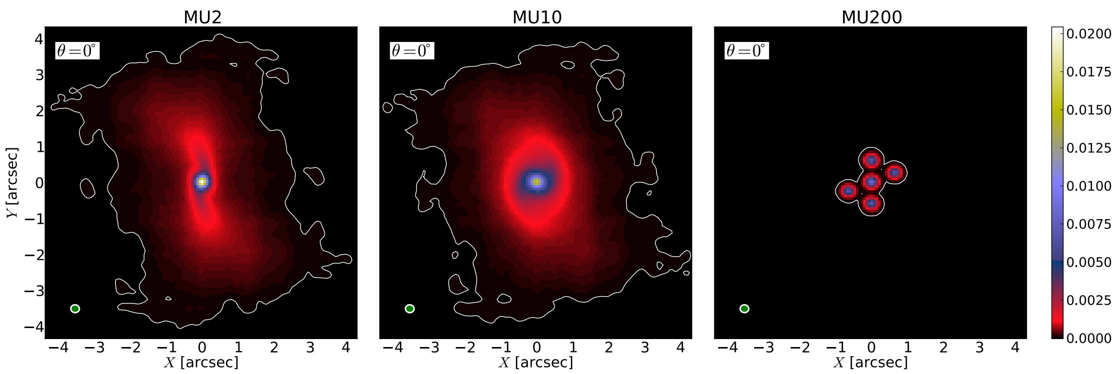

Figure 1: Simulated band 3 observation of a collapsing protostellar dense core with ALMA in configuration 20, viewed face-on. From left to right, the figures correspond to models with a decreasing magnetic field strength. Color scales are in Jy/beam and the size of the synthesized beam is shown in the bottom left corners. Contours correspond to the 3σ sensitivity limit in this band given by the ALMA Sensitivity Calculator, where $\sigma = 14.55\ \mu$Jy for the optimal atmospheric conditions.

P37

Early Star-forming Processes in Dense Molecular Cloud L328 Containing a VeLLO, L328-IRS

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This paper presents the results of mm to sub-mm observations of CO, HCN, and N_2H^+ lines around a dense molecular cloud L328 where three sub-cores reside, one of which harbors a Very Low Luminosity Object (VeLLO), L328-IRS, using several single dish radio telescopes such as SRAO 6m, ASTE 10m, and KVN 21m in order to investigate the early star formation activities in the dense cores where a VeLLO is forming.

Our analysis of the line width first finds that the line is broadened right over the smallest sub-core2 where L328-IRS is located, while it is narrow in other two starless sub-cores, indicating that the VeLLO, L328-IRS, has a direct association with the physical environment in the sub-core2. The other star formation activity, an outflow, is found in the observations. CO observations show that the outflow stems from this VeLLO into a typical bipolar pattern, the blue to NE direction and the red to the SW direction, in a scale of ~ 0.08 pc. The energetics of the outflow from L328-IRS such as such as the momentum flux and outflow effciency is found to be the smallest among the protostars, implying that the VeLLO, L328-IRS, has physical properties that a protostar at the faint end would have. The lower limit of accretion rate derived from the analysis of the CO outflow is about 1.5×10^{-8} $M_\odot$ km s^{-1} year^{-1} which is two orders of magnitude less than the canonical value $\sim 2.0 \times 10^{-6}$ $M_\odot$ km s^{-1} year^{-1} in the standard star formation model. With the correction of the optical depth of CO 3-2 line, mean inclination angle of the outflow, and the low entrainment effciency (0.1) of the outflow, the accretion luminosity is estimated to be as bright as 0.06 $L_\odot$, being similar to the internal luminosity of L328-IRS. This may indicate that the L328-IRS is the case that its faintness can be explained with a very small amount of the accretion rate and thus the resulting accretion luminosity, without relying on the inference of its quiescent accretion phase between episodic outbursts that is usually used to explain the faintness of the VeLLOs.

Inward motions are also found in L328 cloud and its sub-cores with the spectral asymmetry in the molecular lines. The infall signatures are seen around whole envelope area of L328 in the HCN and CO lines, but only toward toward a sub-core with the L328-IRS in N_2H^+ 1-0. Although this line asymmetry seems more complicated by the outflow activity in the very inner region of the cores traced by HCO^+4-3 line, it appears that we are now watching a small clump, L328 which is contracting to make multiple cores and a VeLLO that emanates the outflow.

P38

Fragmentation and age of massive star-forming regions

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In the last decade, we have started to spatially resolve the relatively small gas and dust condensations in high-mass star-forming regions that will eventually become a massive star or system. We call these condensations of sizes on the order of 0.01 pc "cores", and by estimating their masses we can construct the so-called Core Mass Function (CMF) of a region, to compare with the IMF and try to determine the evolutionary process from a core to a star.

For massive star-forming regions, the relationship between the CMF and the IMF is not yet well understood. This is, among other factors, due to the fact that there are not many massive CMF determined. Even then, some of those few CMF seem to tell a story of evolution, by presenting different slopes than that of the Salpeter IMF while others, seem to be very similar to the IMF.

Are we in fact observing regions at different evolutionary stages? One way to answer that is by determining the relative age of those regions, something that can be done by estimating their deuteration. In this talk I will show you the CMFs we obtained for a group of massive star-forming regions with SMA and PdBI observations. These CMFs show different slopes, and we have obtained spectral observations of deuterated molecules to attempt to establish an age scale among them.

P39

Physics and chemistry of strongly irradiated protostars in Corona Australis

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The Corona Australis cloud is one of the nearest (130 pc) active star-forming regions. By the use of far-infrared and (sub-)millimetre observations of the region we study the chemical and physical properties of the surroundings of a handful of low-mass young stellar objects in different stages of evolution (Class 0-III) near the Herbig Be star R CrA. From Submillimeter Array (SMA) and APEX observations we image the region on 400–8 000 AU scales, and find warm (> 30 K) extended molecular gas. Using radiative transfer models, we show that the temperatures observed in the region can indeed be explained by the external heating of the protostellar cores from R CrA (Lindberg & Jørgensen, submitted).

With the Herschel Space Observatory instrument PACS we also image high-temperature (100–1000 K) gas in the region, and compare the results to similar sources in more quiescent regions. Through deconvolution of the line and continuum data, we find that the gas is relatively concentrated towards the protostars, whereas in the continuum shows more extended emission – with a distribution comparable to the molecular gas seen in the millimetre observations.

The unusual physical properties in the region can explain the enhanced abundances of several molecules, especially tracers of photon-dominated regions (PDRs), which have been detected in unbiased submillimetre line surveys of the region using the ASTE and APEX telescopes. The strong external irradiation may also affect the possible formation of complex organics close to the embedded objects. The presence or absence of such molecules can be studied in deep ALMA observations of the region from our ongoing Cycle 0 programme (J. Jørgensen, P.I.), from which we will show the first results. The ALMA data will be used for smaller-scale studies of the physics and chemistry, in particular to study the nature of the chemistry close to the embedded objects.

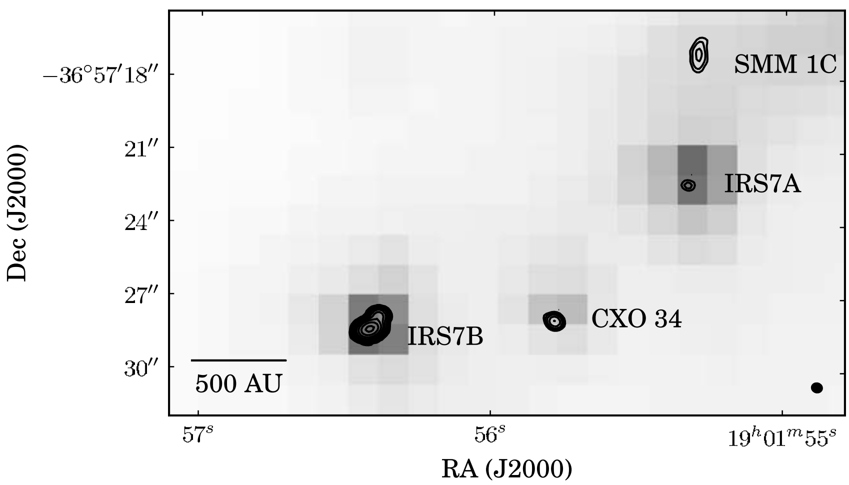

Figure 1: ALMA 0.87 mm continuum (logarithmically spaced contours; Lindberg et al., in prep.) and *Spitzer* 4.5 μm image (greyscale). The ALMA beam size ($0\farcs41 \times 0\farcs37$) is shown in the bottom right corner. Previously only IRS7B and SMM 1C have been detected in the submillimetre.

P40

The Shock Chemistry in Low-mass Star-forming Regions

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Shocked regions ubiquitously exist in interstellar space because supersonic motion of the gas is easily induced by star-formation, supernova, activities of galactic nuclei, and so on. These shocks deeply affect the chemical compositions of each region, and hence, it is interesting to investigate not only physical structure but chemical composition of the shocked gas. However, it is difficult to distinguish the effect of shocks from other interstellar phenomena such as star-formation because of the complexity of general shocked regions. In order to cope with this problem, we have conducted the molecular line surveys in the 3 mm wavelength region with Nobeyama 45 m telescope toward simple shocked regions around low-mass star-forming regions, L1157 mm and L1448 mm.

L1157 B1 is a famous shocked region formed by the interaction between the outflow from the protostar and the ambient gas. A clear evidence of the shock is indicated by observations of the radio emission of SiO and the infrared emission of H_2. The dynamical timescale of the outflow is estimated to be $\sim 10^4$ yr. The angular separation between L1157 B1 and L1157 mm is $\sim 1'$, and hence, we can study the pure shock chemistry apart from the star-forming activity. In the line survey of L1157 B1, we have detected several complex organic molecules such as $HCOOCH_3$, HCOOH, CH_3CHO, and C_2H_5OH. With the aid of the chemical simulation, we have found that some of these complex organic molecules cannot be produced through gas-phase reactions in the dynamical timescale of the outflow from L1157 mm ($\sim 10^4$ yr), and hence, they may mainly be produced on the grain surface, and evaporated into the gas-phase by the shock. In addition, we have detected a phosphorus-containing molecule, PN, in the two shocked regions, L1157 B1 and B2. This molecule was previously detected toward the late-type star such as IRC+10216, and toward massive star-forming region such as Orion KL, Sgr B2, and W51. Our detection of PN is the first case for the low-mass star-forming regions. We have found that the chemical model by Charnley and Millar may be appropriate to explain the production of PN in the shocked region. Their model indicates that PN is produced from PH_3 evaporated from grain mantles through the gas-phase reactions. This model also suggests that the dynamical timescale of the outflow from L1157 mm is enough to produce the certain amount of PN. We could not detect PN toward the protostar L1157 mm, and hence, this molecule could be used as a shock tracer.

In L1448 mm, there are several clumpy structures called bullets, which are formed from internal bow shocks in the extremely energetic jet from the protostar. L1448 B1/R1 are innermost pairs of bullets, each spacing from the protostar by $\sim$ 500 AU. The maximum terminal velocity reaches $\sim$ 80 km s^{-1}, and hence, the dynamical timescale of B1/R1 is estimated to be $\sim$ 10 yr. In the line survey toward L1448 B1/R1, we have detected various fundamental molecules such as HCN, SO, and SiO as detected in L1157 B1. However, we have not detected complex organic molecules. This result has posed a question whether these complex organic molecules cannot be produced in shocked regions around L1448 mm or these molecules are destroyed by the shock. In addition, we could not detect the PN line ($J = 2 - 1$) in the L1448 B1 and R1 in contrast to the L1157 B1 case. It seems that the physical conditions such as the dynamical timescale and the gas kinetic temperature are different from those for L1157 B1, and hence, PN cannot be produced abundantly in L1448 B1/R1. Shock chemistry seems to be different from source to source depending on their physical condition.

P41

Detection of formamide, a key prebiotic molecule, in the solar-type protostar IRAS16293-2422

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Formamide, NH_2CHO, may have been the starting point for the prebiotic species, because, as the simplest possible amide, it contains the functional groups and chemical bonds of central biomolecules, and is a versatile solvent and a reactant (Saladino et al. 2012). Before this work, formamide was detected towards only two high mass star forming clouds, Orion-KL and SgrB2. Recent observations performed with the broad band EMIR receivers at the IRAM 30m telescope towards IRAS16293-2422, combined with spectra from the TIMASSS survey (Caux et al. 2011) allowed us to detect 18 lines at the frequencies predicted by the CDMS database and to firmly conclude to the first detection of this species in a solar-type protostar, likely to give birth to planetary systems like our own.

Assuming that NH_2CHO emission come from a 1.5" source, as derived for many other Complex Organic Molecules (COMs) from interferometric data (Bottinelli et al. 2004, Jorgensen et al. 2011), we obtain from a LTE modeling of the observed emission a formamide abundance relative to H_2 of 1.3 $\times 10^{-10}$, very similar to the abundances derived in Orion-KL and SgrB2 (Turner et al. 1991, Halfen et al. 2011). A simple gas phase chemical model, which assumes that formamide is most likely formed by a neutral radical reaction of H_2CO with NH_2 and destroyed by reaction with the primary molecular ion HCO^+, leads to a formamide abundance at steady-state of 2 $\times 10^{-10}$, in excellent agreement with our observations.

Formamide is also detected in the Hale-Bopp comet (Bockelee-Morvan et al. 2000) . Comparison of the cometary NH_2CHOH_2O abundance ratio, suspected to be representative of the primitive Solar Nebula, with that of IRAS16293-2422, Ori-KL and SgrB2 shows that the cometary ratio is closer to that of the low mass protostar than to the ratios observed the two high mass star forming regions.

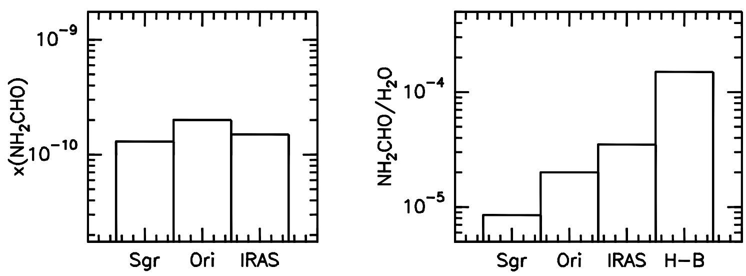

Fig.1 *(left)* Formamide abundances in SgrB2 (Sgr), Orion-KL (Ori) and IRAS16293-2422 (IRAS) ; *(right)* Formamide abundances relative to H_2O in the same sources and in the Hale-Bopp comet (H-B). The H_2O abundances come from Polehampton et al. 2007, Melnick et al. 2010 and Coutens et al. 2012 for SgrB2, Ori-KL and IRAS16293-2422 respectively.

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Halfen et al. 2011, ApJ 743, 60; Jorgensen et al. 2011, A&A 534, A100;
Melnick et al. 2010, A&A 521, L27 ; Polehampton et al. 2007, MNRAS 377, 1122;
Saladino et al. 2012 Chem.Soc.Rev. 41, 5526 ; Turner 1991 ApJS 76, 617.

P42

Observational studies of chemically young dark cloud cores

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We have carried out survey of carbon-chain molecules and NH_3 toward more than 100 nearby molecular cloud cores with the Nobeyama 45m telescope (Hirota et al. 2009). Combining our results with those of previous surveys (Suzuki et al. 1992), we have found a variation of the NH_3/CCS ratio among dark cloud cores and among molecular cloud complexes. For instance, the NH_3/CCS ratios tend to be higher in the Ophiuchus cores than in the Taurus cores. A possible origin of this systematic abundance variation would be due to the difference in the evolutionary stage or the contraction timescale. In addition, we have identified dark cloud cores with remarkably low NH_3/CCS ratios in the Taurus, Aquila, and Cepheus region while there have been no such cores in Ophiuchus (Hirota et al. 2002, 2004, 2011, Hirota & Yamamoto 2006). Some of these cores show lower deuterium fractionation ratios, suggesting lower degrees of molecular depletion (Hirota et al. 2001). We will present detailed results of our survey and mapping observations of chemically young cores.

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P43

High-resolution observations of centimeter/(sub)millimeter H_2O masers in Orion KL with VERA and ALMA

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We will present the latest results of observational studies with VERA and ALMA of a burst event of the H_2O maser in Orion KL, which has been started since 2011 March after 13-year silence (Hirota et al. 2011). According to our monitoring observations with VERA, the total flux of the bursting feature at the LSR velocity of $\sim$8 km s^{-1} reaches 10^5 Jy in 2012 June. It is four orders of magnitudes larger than that of the same velocity feature in the quiescent phase in 2006 but is still weaker by an order of magnitude than those observed in the previous bursts (1979-1985, 1998-1999). We have also carried out VLBI astrometry of the bursting H_2O maser features with VERA and found that their positions are coincident with the shocked molecular gas called the Orion Compact Ridge. It is most likely that the outflow from the radio source I or another young stellar object interacting with the Compact Ridge is a possible origin of the H_2O maser burst. In order to investigate physical properties and pumping mechanisms of the bursting maser features, we proposed follow-up observations with ALMA cycle 0 of the submillimeter H_2O masers and dust continuum emission. To date, we have received the first data of dust continuum observations at band 6 taken in the extended configuration. We found that a compact dust continuum peak is coincident with the position of the bursting maser feature. Detailed analysis will be done based on further continuum data at other bands.

In addition, we will also report on the imaging of the vibrationally excited H_2O maser line at 232 GHz by using the ALMA Science Verification (SV) data of Orion KL (Hirota et al. 2012). This is the first time to detect the vibrationally excited H_2O maser in star-forming regions. We detected the 232 GHz vibrationally excited H_2O maser at the position of the radio source source I while no such feature is found at the position of the bursting maser feature in the Compact Ridge. The spectral profile of the 232 GHz maser shows double-peaked structure at the peak velocities of -2.1 and 13.3 km s^{-1}. It seems consistent with the 22 GHz H_2O masers and 43 GHz SiO masers observed around Source I. Thus, the 232 GHz H2O maser around Source I would be excited by the internal heating by an embedded protostar, being associated with either the root of the outflows/jets or the circumstellar disk around source I.

References:

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P44

Distribution of CCS and HC_3N in L1147

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The ratio hCCS/NH_3h is known as a good indicator of molecular cloud age. Molecular clouds with high hCCS/NH_3h ratios correspond to physically and chemically young (less evolved) phase (Suzuki et al., 1992), which are called CCPR (Carbon Chain Producing Region). However, physical evolution of molecular cloud cores in such a phase is not well known because of small number of such cores. In 2009, we surveyed 40 molecular cloud cores, seeking those with CCS emission with very weak or no emission of NH3, and found five candidates for CCPR (Hirota et al., 2009).

L1147 is one of five CCPR candidates, however, the molecular distribution of CCS has not been known. Therefore we made mapping observations toward L1147 in April 2012, using the 45m telescope of Nobeyama Radio Observatory, NAOJ. Observation frequency was around 45GHz, and we were able to map the source with the J(N)=4(3)-3(2) transition of CCS and the J=5-4 line of HC3N.

Spatial distribution of CCS and HC_3N is elongated in the direction of NE-SW. We found two peaks of CCS emission, whereas a strong peak in HC_3N was found between the two CCS peaks. Such an anti-correlated distribution seems to be rare since both molecules exist in regions where carbon-chain species are rich. We calculated their column densities, assuming that the excitation temperature is 5K, and both lines are optically thin. The column density of CCS was found to be about 10^{12} cm^{-2}, which agrees well with preceding studies of dark nebula (Suzuki et al., 1992) In this paper we report the observation results, chemical and physical implications derived regarding the very young phase of a molecular cloud core.

P45

Masers signposting the structure, dynamics and magnetic fields of star formation within our Galaxy

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I will discuss the results of two recent, complementary maser surveys: the Methanol Multibeam (MMB) survey and the 'MAGMO' survey. These surveys provide an important resource for future ALMA studies and are already being used as tools for ALMA science proposals. The MMB has produced the largest and most complete catalogue of Galactic 6.7-GHz methanol masers to date. These masers exclusively trace regions in the early stages of high-mass star formation and are nearly always associated with mid-IR emission. The longitude coverage and sensitivity of the MMB survey has enabled it to observe most of the Galactic disk, detecting close to 1000 sources. As such it provides a major resource for multiwavelength studies of both high-mass star formation and the structure and dynamics of our Galaxy. 'MAGMO' aims to examine large-scale magnetic fields pervading high-mass star formation regions, through targeted observations of hydroxyl masers towards the sites of 6.7-GHz methanol maser emission from the MMB survey. The Zeeman splitting of the hydroxyl maser emission will determine the strength and orientation of the in situ magnetic field allowing us to test if the orientations of weak large-scale magnetic fields can be maintained in the contraction (and field amplification) to the high densities of high-mass star formation.

P46

The shock chemistry of phosphorus in the L1157 B1 shocked region

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Since shock waves are ubiquitous in interstellar space, a thorough understanding of shock chemistry is important to interpret observed chemical composition. This is particularly true for star-forming regions. For example, outflow gases from protostar bring on shock waves due to collision with surrounding gases.

L1157 dark cloud harbors a low-luminosity Class 0 protostar, which drives a well-collimated molecular outflow. L1157 B1 is a shocked region formed by an interaction between the molecular outflow and ambient gas. Since the B1 position is spatially apart from the protostar, the ”pure” shock chemistry can be investigated. Because of this reason, many observational studies are conducted to investigate physical and chemical condition (e.g. Bachiller & Perez Gutierrez 1997, Hirano & Taniguchi 2001, Sugimura et al. 2011). Especially, recent observations focus on chemical composition (e.g. Arce et al. 2008).

Very recently, Yamaguchi et al. (2011) reported detection of PN for the first time in the L1157 B1 and B2 shocked region. The abundance relative to H_2 is estimated to be $n(\mathrm{PN})/n(\mathrm{H_2}) \simeq (2-6)\times 10^{-10}$ towards B1 and $(3-7)\times 10^{-10}$ towards B2. More recently, a subsequent work (Yamaguchi et al. in prep) reported that PO is *not* detected at B1; the upper limit of PO abundance relative to H_2 is 2.5×10^{-10}. Chemistry of P-bearing species has been investigated in the pseudo-time dependent model (e.g. Charnley & Millar 1994). For example, Charnley & Millar (1994) investigated P-chemistry in the hot core model, in which they assumed a constant warm temperature (100K-300K) and high density (2.0×10^7 cm^{-3}) , and showed that PN can be produced enough to be observed. But shock chemistry calculations that especially focus on p-bearing species have not been conducted.

In this work, we study the evolution of the P-bearing species in a 1D C-shock model. Temporal variations of physical parameters (density and temperature) are adopted from Jimenez-Serra et al. (2008). We found that observed abundance of PN can be reproduced in a C-shock model with v=20km s^{-1}, n=2.0×10^4 cm^{-3} , only if the N atom abundance is high($n(\mathrm{N})/n_{\mathrm{H}} \sim 10^{-5}$) in the pre-shock gas.

P47

Can Thermal Instability Grow behind a Shock Wave in HI and Molecular Clouds?

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Thermal instability is an important physical process to determine the structure in the interstellar medium. It is widely known that low and mid-temperature parts of the interstellar medium (ISM) is consist of warm and cold neutral medium (WNM and CNM; e.g. Heiles & Troland 2003). Field, Goldsmith & Habing (1969) calculated the thermal equilibrium state considering the cosmic ray heating and line emission(H, O, C[II]) coolings. They showed that there are three physical states under the pressure equilibrium: two stable states of CNM and WNM and one unstable state. The thermal instability is considered to be the origin of the tiny scale structures which have been detected HI gas (e.g., Heiles 1997) and molecular cloud (e.g. Langer et al. 1995; Sakamoto & Sunada 2003; Tachihara et al. 2012). Many authors have studied the dynamical condensation (fragmentation) process of the ISM driven by thermal instability in the shocked layer of WNM. Koyama & Inutsuka (2000; 2002) show that tiny clumps of CNM are formed as a result of thermal instability in the layer compressed by shock propagation (see also, Hennebelle & Perault 1999, Hennebelle & Audit 2007, Heitsch et al. 2008, Vázquez-Semadeni et al. 2007). Recently, Inoue & Inutsuka (2008, 2009, 2012) studied the analogous process, including the effect of the magnetic field, and showed the generation of sheetlike HI clouds and molecular cloud. While the thermal instability in the condensation process of WNM to CNM have been studied intensively, its role in CNM and the molecular clouds has not yet been examined. Because the interstellar clouds are known to be always turbulent with supersonic velocity dispersion (Larson 1981, Solomon et al. 1987, Heiles & Troland 2005), detailed study of the effect of thermal instability in the shocked cloud must be explored.

Using one-dimensional hydrodynamics simulations with the effects of detailed cooling, heating and chemical processes, we examine thermal stability of shocked gas in HI and molecular clouds. We also estimate the e-folding time of the thermal instability to obtain the degree of perturbation grow in shocked gas. We find that both HI clouds and molecular clouds can be thermally unstable in the cooling layer behind the shock wave. Seed density perturbations in HI cloud can grow exp(5)$\simeq$ 150 times larger than the initial state, while perturbations in molecular cloud can grow roughly exp(1) $\simeq$ 2.7 for high Mach number shock. These results suggest that, in order to discuss fine structures in the clouds, the isothermal approximation may not adequate in CNM and molecular cloud.

P48

Chemistry and the "Prestellar" or "Starless" Nature of the Infrared Dark Cloud (IRDC) G028.23-00.19

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From the studies of Rathborne et al. (2010) and Sanhueza et al. (2012), we have identified an excellent candidate to study the initial conditions of massive star formation. The Infrared Dark Cloud (IRDC) G028.23-00.19 appears to be in a very early stage of evolution because it is dark at *Spitzer*/IRAC 3.0, 4.5 and 8.0 μm, *Spitzer*/MIPS 24 μm and *Herschel*/PACS 70 μm. Located in its center, MM1 is one of the most massive, IR quiescent clumps known with $\sim$700 $M_\odot$ (Rathborne et al. 2010). In addition to the mass, the high density and the size are also comparable to the values in regions with ongoing massive star formation, except for the low dust temperature ($\sim$20 K). These characteristics suggest MM1 will form high-mass stars in the future. We have observed this source with CARMA at 3 mm in the most compact configuration (11" angular resolution), obtaining intriguing results from the different molecular lines detected (NH_2D, $H^{13}CO^+$, SiO, $HN^{13}C$, C_2H, HCO^+, HNC, N_2H^+, and CH_3OH). The bright and compact NH_2D emission associated with MM1 indicates that the deuterated fraction is high, suggesting that the most massive clump in the IRDC is in a very early phase of star formation (Caselli et al. 2002). N_2H^+, $H^{13}CO^+$, and $HN^{13}C$ show similar spatial distributions to that of the 1.2 mm emission from the 30 m IRAM telescope (11" angular resolution; Rathborne et al. 2010). One would think that this IRDC is in a "prestellar" phase based on the strong detection of NH_2D and the absence of IR sources associated with the cloud. However, unexpected SiO emission with broad and narrow lines widths in the periphery of MM1, and CH_3OH emission spread throughout the whole IRDC may suggest something different. It is well known that SiO is a tracer of shocks (usually indicating molecular outflows) and CH_3OH is normally associated with active star-forming regions. In this work, we discuss different mechanisms that can form SiO and CH_3OH, and the "prestellar" or "starless" nature of the IRDC. The IRDC G028.23-00.19 is a great candidate to be studied in detail with the high sensitivity and dynamic range that ALMA offers.

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P49

Two-Stage Fragmentation for Cluster Formation

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We extend the linear analysis of the non-ideal magnetohydrodynamic equations for a model planar molecular cloud to apply to the context of clustered star formation. This analysis has shown that the time and length scales for the collapse of a cloud depend strongly on ambient cloud properties, including density, ionization fraction and mass-to-flux ratio. We propose and show that the collapse time and length scales for substructures (subclumps) within a collapsing macro structure (clump) can be dramatically smaller than for the macro structure itself. This analysis accounts for the transition from the ultraviolet to cosmic ray dominated ionization regimes of the cloud. The varying collapse times and lengths for the clumps versus subclumps implies that cluster formation can be achieved through a hierarchical two-stage fragmentation process within a molecular cloud. Comparisons to several observed regions and implications for future ALMA observations will be discussed.

P50

Line-Survey Observations at 82-106 GHz and 335-355 GHz toward Outflow-Interacting Region, OMC-2/FIR 4

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Enormous progress has been achieved in the past few decades in studying chemical composition of dense molecular gas associated star forming regions. The chemical composition and evolution in dense interstellar medium themselves are of particular great interest. In addition, they are very useful for the diagnostics of protostar or protoplanetary disk evolution, also of shocks and the energy sources of extragalactic nuclei. Shock chemistry is one of keys to understand chemical composition of ISM (interstellar medium) because shock waves are ubiquitous; especially evidence for shock is usually observed in outflow and jet associated star formation. Shock chemistry is, however, still in evolving phase, although the theoretical study has been extensively made since 1980's (McKee & Hollenbach 1980, Neufeld 1995). One of well-studied shocked regions is L1157 B1. Recently, spectral line surveys have been performed in the wavelengths, 3-mm and 500-μm, and have revealed chemical composition in outflow-shocked region (Codella et al. 2010, Sugimura et al. 20011). Physical and Chemical influence depend on the condition of peripheral medium and shocked velocity. Thus, to unveiling these influence, we have to observe the varied outflow shocked regions. OMC2-FIR4 (d=400pc) is one of the most suitable target to investigate these influence, since the NMA (Nobeyama Millimeter Array) and ASTE (Atacama Submillimeter Telescope Experiment) observations have revealed that an FIR3 outflow interacts with a dense gas associated with FIR4 from three kinds of evidence (Shimajiri et al. 2008). One is a morphological evidence that the distribution of the southern lobe of FIR3 outflow coincides with that of the FIR4 dense gas. Others are chemical and kinematical evidence that the shock tracers, SiO and CH_3OH emissions distribute at the tip of the outflow and that an increment of the velocity width at the interface between the outflow and dense gas is seen in $H^{13}CO^+$, SiO, CH_3OH, and CO. Furthermore, dusty cores are not associated with any MIR source in FIR4 (Adams et al. 2012).

We have been completed 3-mm (82-106GHz) and 850-μm (335-355GHz) line surveys of FIR4 (i.e., southern lobe of FIR3 outflow) as well as FIR3 and FIR3N (the northern lobe) using NRO 45m and ASTE. FIR4 is found to be obviously chemically enriched; the best among three regions (FIR3N, FIR3, and FIR4). Our 3-mm and 850-μm line survey detected 122 lines and 21 species (and their 11 isotopes) including CH_3CCH, CH_3CHO, and C_3H_2 as well as S-bearing molecules such as H_2CS, SO, and HCS^+. From the comparison among spectra of three positions, we have found that S-bearing molecules such as SO, CS, $C^{34}S$, H_2CS molecules and SiO emission has a wing components only at FIR 4. Furthermore, the velocity width of these molecules is significantly larger ($\sim$5-10 km s^{-1}) than that ($\sim$1.5 km s^{-1}) of the dense gas tracer such as $H^{13}CO^+$ line. It is possible that these molecules trace the shock. We have detected toward FIR4 many CH_3OH lines with different upper state energies (E_u=16-260K) with our line surveys, and it was found that CH_3OH lines consist of low and high velocity components. Using multi-transition data of CH_3OH, we made the rotational diagram. It was clearly revealed that rotational temperature of high velocity components is surprisingly up to $\sim$210K. These results suggest that the FIR 4 region is heated by the outflow shock.

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P51

Observations of Deuterated Species toward Low-Mass Prestellar and Protostellar Cores

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We have conducted the observation ground state transition lines of fundamental deuterated species, DCO^+, DCN, CCD and N_2D^+ with Nobeyama 45 m telescope by using the newly installed receiver, T70. The observed targets are TMC-1, Lupus-1A, L1527, IRAS15298-3359 and IRAS16293-2422. The former two sources are starless cores, harboring extremely abundant carbon-chain molecules. The latter three sources are star-forming regions. L1527 and IRAS15398-3359 are representative sources of warm carbon chain chemistry, and IRAS16293-2422 is a representative source of hot corino chemistry. Accurate determination of the deuterium fractionation ratios in these sources is of fundamental importance, particularly for comparison with chemical models.

Toward L1527, we have detected $D^{13}CO^+$ in addition to DCO^+, and have found that the peak intensity of $D^{13}CO^+$ (0.13 K) is much higher than that expected from the intensity of DCO^+ (1.5 K). This means that the DCO^+ line is not always optically thin. Considering the interstellar $^{12}C/^{13}C$ ratio of 60, optical depth of the DCO^+ line is estimated to be 4. This result indicates that we should consider more seriously about the optical depth of DCO^+, when we derive the deuterium fractionation ratio towards dark cloud cores.

We have calculated the deuterium fractionation ratios by considering the optical depth effect. We first derive excitation temperatures from $H^{13}CO^+/HC^{18}O^+$ ratios. Then, we estimate the optical depth of each molecule. As a result, DCO^+/HCO^+ is found to be 1.8%, and DNC/HNC to be 4.1% in TMC-1, for example. The deuterium fractionation ratios in the other sources will also be presented and discussed in relation to the source characteristics.

P52

Mapping observations of the NH_3 (1,1), (2,2) and (3,3) in the Horsehead Nebula and the NGC 2023 region with the Nobeyama 45 m telescope

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The horsehead nebula is a dark cloud located in the Orion B GMC, where massive clusters are forming (e.g., Bally et al. 2008), and NGC 2023 is a bright reflection nebula illuminated by the B1.5 star HD 37903 (Abt & Levato et al. 1977). We performed mapping observations of the Horsehead Nebula and the NGC 2023 region in the NH_3 (1,1), (2,2) and (3,3) lines with the Nobeyama 45 m telescope to search for dense cores which have potential for star formation. As a result, we succeeded in identifying five dense cores (Cores A-E) in the two regions. Furthermore, we analyzed the hyperfine structure of the NH_3 inversion transition and derive the masses and temperature of the cores. Core A in the Horsehead Nebula has a mass of 22 ± 29 $M_{\odot}$, comparable to its virial mass of 56 ± 36 $M_{\odot}$, which agree with the previous estimates by Johnstone et al. (2006). The gravitationally bound state of the core is consistent with the on-going star formation in the Horsehead Nebula. In addition, the column density of the core becomes maximum on its east side, while the temperature becomes maximum on its west side. These facts suggest that the ionization of the molecular gas by IC 434 proceeds from the west part of the core. Core B is newly found by this study toward the boundary area between the Horsehead Nebula and NGC 2023. Both the column density and velocity width of the core become the largest at the core center, suggesting the possibility of infalling motion. Note that the core temperature increases toward the northern and southern outer parts. This fact might indicate that the ionized gas from IC 434 affects the evolution of the core. Cores C, D, and E in NGC 2023 have masses of $26 \pm 23,\ 11 \pm 15,\ \mathrm{and}\ 35 \pm 27$ $M_{\odot}$, respectively. Cores D and E are found to be gravitationally bound, consistent with the presence of protostars (Meyer et al. 2009). Core C, however, has a large virial mass of $130\pm\ 98 M_{\odot}$, and dose not seem bound. It is likely that the non-thermal gas motion in Core C is caused by the random motion of six compact and dense substructures traced by the 850 μm continuum emission (Johnstone et al. 2006). In addition, the highest temperature of Core D is likely to be caused by the interaction with the outflow from the protostar MM1 (Sandell et al. 1999).

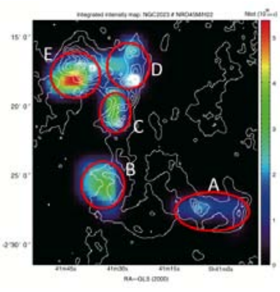

Figure 1: NH_3 total column density map (color) superposed on the 850 μm dust continuum map (contour). The color bar on the right-hand side of the panel shows the column density scale in 10^{14} cm^{-2} The contour intervals are 0.2 mJy beam^{-}1, starting from 0.01 mJy beam^{-}1. The red lines indicate the spatial extents of our identified cores A, B, C, D, and E.

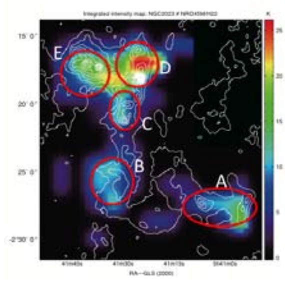

Figure 2: Temperature map (color) on the 850 μm continuum one (contour). The color bar on the right-hand side of the panel shows the temperature scale in K. The parameters of the contours are the same as in Figure 1.

P53

The VLBI Imaging Survey of the 6.7 GHz Methanol Masers using the JVN/EAVN

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The process through which high-mass star forms has been a matter of debate for many years. The evolution of the disk around high-mass young stellar objects (HMYSOs), however, remains largely unknown in particular. Important questions yet to be solved include: 1) What is the rate of accreting matter infalling to the central star?; 2) When does the accretion from the disk stop?; 3) When does the disk evaporate? These issues should be addressed by a combination of Very Long Baseline Interferometer (VLBI) for dynamics and the ALMA observations for physical parameters.

In this presentaion, we show a result of the VLBI imaging survey for the 6.7 GHz methanol masers by using the Japanese VLBI Network (JVN) and the East-Asian VLBI Network (EAVN). This maser is one of the best tracer for studies of the rotating disk around high-mass young stellar objects (YSOs), and can directly provide 3-dimensional velocity information (not only radial but also tangential velocities) using the VLBI technique for measuring proper motions. We obtained VLBI images as spatial distributions of 36 methanol maser sources observed in August 2010 and November 2011, which were 1st epoch to measure proper motions. All of observed sources provide new VLBI images except for one source, and the spatial morphology were classified into five categories similar to the results by the European VLBI Network observations (Bartkiewicz et al. 2009, A&A, 502, 155). In the categories, the methanol masers showing ellipse and linear spatial morphologies (e.g., as shown in figure 1) could be interpreted to trace the rotating disk with some inclinations and seen from edge-on, respectively. These sources can be good candidates for the investigations of the evolution of the disk around HMYSOs. We will also present timeline of JVN/EAVN observations to measure proper motions in 2012 and 2013.

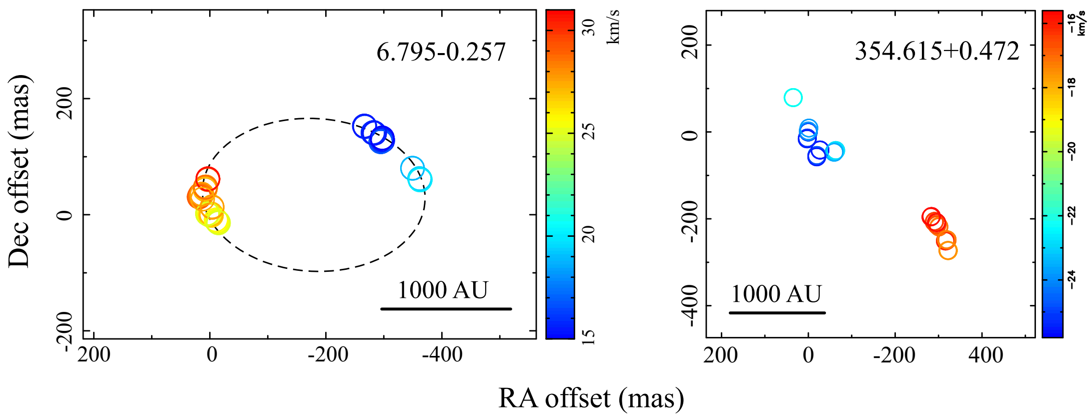

Figure 1. Spatial distributions of the 6.7 GHz methanol maser spots as target sources in this proposal observed using the EAVN in August 2010 (left: G6.795−0.257 (ellipse), right: G354.615+0.472 (linear)). In each panel, the spot sizes are fixed and the color indicate its radial velocity (see color index at the right for each source). The position of each spot is relative to the reference spot at the origin of the each map. The dashed ellipses show the best-fitting result to the methanol maser spots.

P54

Statistical Equilibrium Calculations of OH: Interpretation of the 1612 MHz Absorption Line in HCL2

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The 18 cm Λ-type doubling transition has extensively been observed toward diffuse and translucent clouds, massive star forming regions, supernova remnants, AGB stars, and AGN, since its discovery toward Cas A by Weinreb et al. (1963). However, it has not been studied well for cold dark clouds.

We have recently observed four hyperfine components (1612 MHz, 1665 MHz, 1667 MHz and 1720 MHz) of the ground state Λ-type transition of OH toward several positions in Taurus Molecular Cloud with the Effelsberg 100 m radio telescope. In this observation, we have found that the 1612 MHz line appears in absorption toward the southeast position of HCL2, where the [CI]($^3P_1$-$^3P_0$) emission shows a local peak. Furthermore, the spectrum observed toward the other position in HCL2 shows two velocity components. The higher velocity component is seen in absorption, whereas the lower velocity component is seen in emission. The absorption is against the cosmic background radiation, because there are no bright continuum sources toward these directions.

In order to understand the above results, we have made statistical equilibrium calculations of the OH molecule. The collisional cross sections of OH are taken from RADEX (Offer et al. 1994). Since they are different between ortho- and para-H_2, we considered the orho-para ratio in addition to the gas kinetic temperature and the H_2 density. As a result, we found that the 1612 MHz line appears in absorption only when the temperature is higher than 40 K. For instance, the temperature is determined to be about 50 K for the southeast position of HCL2, where the pure absorption line is observed. In this case, the ortho-para ratio, the column density and the H_2 density are evaluated to be 2, 3×10^{14} cm^{-2}, and $10^2 \sim 10^6$ cm^{-3}, respectively. Intensities of the four hyperfine components of OH are found to be sensitive especially on the ortho-para ratio and the temperature. The derived temperature seems quite high in comparison with the typical gas kinetic temperature of cold dark clouds (~10 K). The absorption features would originate from a diffuse envelope, where the UV radiation can penetrate. The combination of emission and absorption observed in HCL2 would reflect a cloud structure like cold dense cores surrounded by a less-dense envelope.

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P55

Abundant CH_3OH in the Cold Starless Core TMC-1

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Methanol (CH_3OH) is generally abundant in star-forming regions (e.g. Blake et al. 1987; van Dishoeck et al. 1995). It is thought to be produced mainly on grain mantles, and is released into the gas phase by various star-formation activities. Since its abundance is apparently enhanced in the shocked region such as L1157B1 (e.g. Avery and Chiao 1997; Bachiller and Pérez Gutiérrez, 1997; Nisini et al., 2010), CH_3OH is sometimes used as a shock tracer. However, CH_3OH is moderately abundant even in cold starless cores like Taurus Molecular Cloud-1 (TMC-1) (T_k ~10 K), although no heating sources are embedded there. Since evaporation temperature of CH_3OH is about 100 K, existence of CH_3OH in TMC-1 is puzzling. While the production pathway in the gas phase is proposed (e.g. Van der Tak et al. 2000), it cannot explain the observed abundance of CH_3OH in TMC-1.

Recently, we have conducted high velocity-resolution observations of CH_3OH in TMC-1. We have found that the line shape of CH_3OH is much different from those of other carbon chain molecules toward TMC-1(Cyanopolyyne Peak; CP), which indicates different distribution of these two species in the core. We have also conducted mapping observations of $CH_3OH(J_k = 2_k - 1_k)$, $C^{34}S(J = 2 - 1)$ and $C^{18}O(J = 2-1)$ in the 150"×150" area around TMC-1(CP), and revealed that the distribution of CH_3OH is anticorrelated with that of $C^{34}S$. This difference would be an important clue to understand the mechanism for production of CH_3OH in TMC-1.

We are considering two possible mechanisms for desorption of CH_3OH from grain mantles in starless cores. One is soft shock caused by collisions of small clumps inside the core and/or accretion motions of envelope materials onto the core, whereas the other is desorption by cosmic-ray induced UV. In any case, the distribution of CH_3OH would not follow the distribution of the dense gas (CS), being consistent with our observation. It therefore seems likely that the molecular composition in the gas phase would significantly be affected by non-thermal desorption processes of grain mantles in starless cores.

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P56

The 0.8 mm Spectral Line Survey toward Low-Mass Protostellar Cores with ASTE

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Recently, it has been pointed out that the chemical composition in the low-mass protostars varies from source to source. Two extreme cases are the hot corinos where various complex organic molecules are abundant, and the WCCC (Warm Carbon-Chain Chemistry) sources where carbon-chain molecules are abundant. Sakai et al. (2009) proposed that the duration time of a starless core stage causes the difference in chemical composition. If the duration time is close to the free-fall time, atomic carbon can directly stick onto the grain mantles before converted into CO in the gas phase. Then, atomic carbon is converted into CH_4 through hydrogenation reactions on the grain mantles. If the duration time is longer, CO is absorbed on the grain mantles, and the absorbed CO will be converted to CH_3OH and possibly to complex organic molecules. Understanding an origin of such chemical diversity is an important target for astrochemistry.

We have performed a spectral line survey in the 332 - 364 GHz band with the ASTE 10 m telescope toward two low mass class 0 protostars R CrA IRS7B (Watanabe et al. 2012) and Serpens SMM4. R CrA IRS7B has been recognized as a hot corino candidate because of its bright emissions of H_2CO and CH_3OH. Serpens SMM4 is a hot corino, since complex organic molecules, such as $(CH_3)_2O$, are detected.

In total, 16 fundamental molecular species including CO, CS, CN, NO, CCH, c-C_3H_2, HCO^+, H_2CO and CH_3OH are identified in R CrA IRS7B. Strong emissions of CN, and CCH are observed, whereas, complex organic molecules and long carbon-chain molecules are not detected. The rotation temperature of CH_3OH is evaluated to be $\sim$ 31 K, which is lower than that in the typical hot corino IRAS 16293-2422 ($\sim$85 K; van Dishoeck 1995). The deuterium fractionation ratio for CCH and H_2CO are obtained to be 0.05-0.04, which are an order of magnitude lower than that found in the hot corino. Furthermore c-C_3H_2, whose production pathway is related to carbon-chain molecules, is abundant, and its rotation temperature is similar to that of CH_3OH. From these results, it is likely that the R CrA IRS7B is a source with a mixture of these two chemical characteristics. The UV radiation from nearby Herbig Ae star may also affect the chemical composition.

For Serpens SMM4, 12 molecular species are identified, including fundamental molecules, whereas complex organic molecules and long carbon-chain molecules are not detected. The chemical composition of Serpens SMM4 is found to be similar to that of the hot corino source IRAS 16293-2422. Indeed, the CH_3OH/H_2CO ratio in Serpens SMM4 is close to those reported for hot corino sources rather than those for WCCC sources. Nevertheless, the rotational temperature of CH_3OH, the deuterium fractionation ratio of $HDCO/H_2CO$, and the abundances of sulfur-bearing molecules are all lower than those in IRAS 16293-2422. Our survey demonstrates further chemical diversity in low-mass protostars.

By comparing the column density ratios $N(CH_3OH)/N(H_2CO)$ among low-mass protostars, we found that the ratio tend to be higher for hot corino sources than for WCCC sources. R CrA IRS7B has an intermediate value between them. The source-to-source difference of the $N(CH_3OH)/N(H_2CO)$ ratio may also reflect the duration time of the starless core phase. According to the chemical model by Taquet et al. (2012), the CH_3OH/H_2CO abundance ratio on dust grains increases as a function of time. This is because the hydrogenation rate is determined by a constant flux of H atoms falling onto dust grains. The CH_3OH/H_2CO abundance ratio would be a useful indicator to characterize the chemical composition of low-mass protostar cores.

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P57

Atlas and Catalog of Dark Clouds Based on the 2 Micron All Sky Survey. II. Correction of the Background Using the Besançon Galaxy Model

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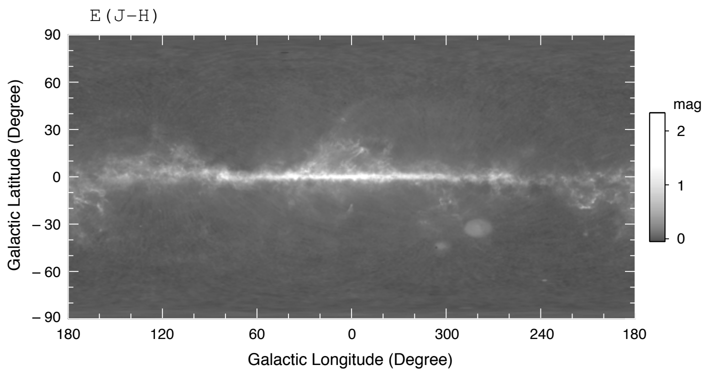
We have applied a correction to the large scale color excess maps of $E(J-H)$ and $E(H-K_S)$ derived by Dobashi (2011) based on the 2 Micron All Sky Survey Point Source Catalog (2MASS PSC; Skrutskie et al. 2006). These maps were produced using a new technique named X percentile method, and they cover all of the sky at the $1'$ grid with a deep threshold magnitude set of $(m_J, m_H, m_{K_S}) = (16.0, 15.5, 15.0)$ mag. The maps, however, suffer from an apparent error on a large scale arising from an ambiguity in determining the background star colors necessary to define the zero point of the color excess. The error is relatively large in the inner region of the Galaxy at $|l| < 90°$, and the maps may overestimate the true extinction by a few magnitudes in A_V in the inner region. In order to improve the background determination, we performed a Monte-Carlo simulation to generate a star catalog equivalent to the 2MASS PSC based on the Besançon Galaxy Model described by Robin et al. (2003). The simulated catalog contains $\sim 7.7 \times 10^8$ stars whose apparent magnitudes in the J, H, and K_S bands are calculated assuming no interstellar dust throughout the Galaxy. We applied the X percentile method to the simulated star catalog in the same way as done by Dobashi (2011) to the 2MASS PSC, and regarded the resulting star color maps as the background of the color excess maps. As a result, the overestimation in the original color excess maps has been significantly improved. Extinction maps of A_J, A_H, and A_{K_S} made by Dobashi (2011) were also improved utilizing the resulting color excess maps. We further investigated possible errors arising from the X percentile method itself by setting an artificial diffuse dust disk in the simulated star catalog, and found that the diffuse dust on a large scale can be underestimated by $\sim$ 20 % for the galactic latitude range $|b| > 5°$ at most, which should be noted when the color excess maps corrected are compared with other dataset including the far-infrared dust emission detected by Planck and Herschel.

The new color excess and extinction maps are open to the public, and are available at our website " http://darkclouds.u-gakugei.ac.jp/" or " http://astro.u-gakugei.ac.jp/~tenmon/Atlas/index.html".



An example of the color excess maps corrected using the Besançon Galaxy Model by Robin et al. (2003).

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P58

Nobeyama 45m telescope legacy project: Line survey of L1527

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L1527 (d = 140 pc) is known to be a low-mass Class 0 source in Taurus Molecular Cloud. In this source, various carbon-chain molecules are abundant in the warm and dense region around the protostar. This would be the result of warm carbon chain chemistry (WCCC); carbon-chain molecules are regenerated, triggered by evaporation of CH_4 from grain mantles. In order to characterize this new chemistry and to compare it with chemical compositions of other star-forming cores, we have conducted sensitive line survey observations with the Nobeyama 45 m telescope as the NRO legacy project (2008-2012).

We have covered the whole 3 mm band from 79 to 117 GHz. In addition to various carbon-chain molecules, we have detected fundamental molecules, CO, CS, and N_2H^+ and their isotopic species, ^{13}CO, $C^{18}O$, $C^{17}O$, ^{13}CS, and $C^{34}S$ in this observation. Furthermore, we have detected many lines of oxygen bearing molecules, SO, HCO, HCNO, C_3O, CH_3OH, cycopropenone, and HC_3HO. Various deuterated species are also detected. In particular, we have detected c-C_3D_2 and c-C_3D for the first time in interstellar clouds. The spectral pattern of L1527 is completely different from that of the hot corino source, IRAS16293-2422, reported by Caux et al. (2011), indicating the chemical diversity of low-mass star-forming cores. We have also compared the chemical composition of L1527 with TMC-1. Basically, their abundances are similar to each other. However, the abundances of nitrogen containing species in L1527 tend to be lower than those in TMC-1. Longer chain species also tends to be less abundant in L1527. These results clearly indicate the different production mechanism of carbon-chain molecules in the warm region.

P59

Deuterium Fractionation in Low-Mass Star Forming Regions

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It is well known that deuterium fractionation in molecules is enhanced in cold evolved starless cores due to the time evolutionally effect and the CO depletion. Hence, it has extensively been employed to trace the evolutionary stages of starless cores. On the other hand, it is still controversial how the deuterium fractionation ratio changes after the onset of star formation. When a protostar is formed in a dense core, the temperature is raised up in the vicinity of the protostar. Since the equilibrium deuterium fractionation ratio is lower for higher temperature, the deuterium fractionation ratio near the protostar should start to decrease toward the new equilibrium ratio at the elevated temperature[1],[2]. However, decrease of the deuterium fractionation ratios is expected to be slower for neutral species than ionic species because of longer lifetime of neutral species in star forming regions. In fact, many neutral deuterated spiecies have been detected toward star forming regions[3],[4],[5]. This means that the deuterium fractionation ratio of neutral spiecies will be preserved even after star formation. By use of this behaviour, the initial condition would be obtained from observations of neutral deuterated spiecies. In order to explore this possibility, we have investigated the spatial distribution of the deuterium fractionation ratios of a few molecules toward two representative low mass star-forming regions, L1551 (Class I) and IRAS16293-2422 (Class 0).

With the Nobeyama 45 m telescope, we have observed the $J = 1 - 0$ lines of DCO^+, $H^{13}CO^+$, DNC, $HN^{13}C$, N_2D^+, N_2H^+. We have conducted 5-point strip observations centred at the protostar position. For L1551, the $DCO^+/H^{13}CO^+$ ratio toward the protostar position is found to be decreased in comparison with those of other positions. On the other hand, the $DNC/HN^{13}C$ ratio does not show such a central dip. For ionic spiecies such as DCO^+ and $H^{13}CO^+$, the dissociative electron recombination is their main destruction mechanism, and the lifetime is a few 100 years. In contrast, the major destruction pathway for the neutral species like DNC is the ionic destrution by H^+, H_3^+, and He^+, and the timescale is as long as 10^4 - 10^5. Therefore, the $DCO^+/H^{13}CO^+$ ratio quickly decreases after the temperature rise, whereas the $DNC/HN^{13}C$ ratio remains for a while as it was in the cold starless stage.

On the other hand, we have not been able to find decrease of the N_2D^+/N_2H^+ in L1551 in contrast to the above prediction. This seems to be due to depletion of N_2H^+ (and N_2D^+) in the vicinity of the protostar. Since N_2H^+ (and N_2D^+) is destructed by CO which is evaporated from the dust grains in the warm region, the N_2H^+ (and N_2D^+) line would mainly trace the cold envelope. Hence, the N_2D^+/N_2H^+ ratio does not show significant decrease toward the protostar position due to overwhelming contribution of the cold envelope. The effect of the cold envelope is found to be more significant in the Class 0 object, IRAS16293-2422. Toward this source, even $DCO^+/H^{13}CO^+$ ratio does not decrease toward the protostar position, as well as the $DNC/HN^{13}C$ and N_2D^+/N_2H^+ ratios. In order to trace the deuterium fractionation ratios in the vicinity of protostars, high spatial resolution observations in the submillimetre region would be essential.

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P60

The Dynamical State of A Filamentary Infrared Dark Cloud, Serpens South

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We present the results of ^{12}CO ($J = 2-1$), ^{13}CO ($J = 2-1$), C^{18}O ($J = 2-1$), and N_2H^+ ($J = 1-0$) mapping observations toward the nearest filamentary infrared dark cloud, Serpens South, using the CSO 10.4 m and NRO 45m telescopes. The ^{13}CO ($J = 2-1$) lines show significant blue-skewed shapes over the whole observed area, suggesting the global infall motions toward the cluster-forming clump. From the C^{18}O emission, the clump mass and velocity width are estimated to be 260 $M_\odot$ and 1 km s^{-1}, respectively. Applying a hyperfine fitting to the N_2H^+ ($J = 1-0$) emission, we derive the spatial distributions of the physical quantities such as the column density, excitation temperature, and the velocity width, which indicate the dynamical interaction between the molecular outflows and dense gas. We identify over 30 dense cores using clumpfind. We find that the identified cores are out of virial equilibrium, although the whole cluster-forming clump is close to a virial equilibrium, and the ambient turbulent pressures significantly contribute to the core dynamics.

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Cluster formation in the Sh247/ Sh252/ BFS52 regions

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We present results of the observations carried out toward the Sh247, Sh252, and BFS52 H II regions with the $J = 2-1$ emission lines of ^{12}CO, ^{13}CO, and C^{18}O using the 1.85m radio telescope of Osaka Prefecture University installed at the Nobeyama Radio Observatory (NRO). We also carried out high angular resolution mapping observations with various molecular emission lines, i.e. ^{13}CO($J = 1-0$), C^{18}O($J = 1-0$), SO($J_N = 3_2 - 2_1$), CS($J = 2-1$), C^{34}S($J = 2-1$), and C$_3$S($J = 17-16$), toward 11 limited areas in the above three H II regions using the NRO 45 m telescope.

The molecular clouds associated with Sh247, Sh252, and BFS52 are well-studied star formation regions which are characterized by ultra-compact H II regions, high mass young stars, and embedded IR clusters. Previous studies evidenced molecular clouds in the regions as well as active star formation occurring therein (e.g., Kömpe et al. 1989; Carpenter et al. 1995). We found that there are at least 10 young IR clusters as seen in the 2MASS images within the observed region.

In our 1.85 m observations, most of the ^{12}CO ($J = 2-1$) emission line is found in the LSR velocity range between -5 and 15 kms^{-1}, which changes smoothly over the entire region, indicating that the molecular clouds associated with the three H II regions are physically connected on a large scale. We found that there are two velocity components in ^{12}CO, and also that their distributions show an anti-correlation. The IR clusters are located at their interfaces, suggesting that the two components may be colliding against each other, which induced the formation of the clusters.

In our 45 m observations, we revealed the distributions of the various molecular emission lines for the 11 limited areas. Based on the $J = 1-0$ lines of ^{13}CO and C^{18}O, we have identified 15 clumps in these regions. Among the 15 clumps, 10 clumps are associated with the IR clusters. The other 5 clumps are not associated with any known young stellar objects or IR clusters. We investigated the variations of velocity dispersion in the $J = 2-1$ line of ^{13}CO, $J = 1-0$ lines of ^{13}CO and C^{18}O of the 15 clumps as a function of the radius from the cluster center or the center of the clumps. We found that there is a difference in their velocity distributions between the clumps with and without IR clusters. The clumps with clusters tend to have larger velocity dispersion increasing with distance from the cluster center. In contrast, clumps without clusters show a flat velocity dispersion with increasing radius. The difference of the distributions in the velocity dispersion suggests that conditions in a turbulent medium are needed for cluster formation.

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P62

Nobeyama 45m Telescope Legacy Project: Line Survey of IRDC G28.34+0.06

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What constitutes the initial condition for massive star formation is still not well characterized. The cold and dense nature with substantial masses of infrared dark clouds (IRDCs), objects seen in absorption against the bright diffuse Galactic mid-infrared background, strongly suggests that IRDCs are sites for massive star and cluster formation. To achieve a more complete and unbiased census of the physical and chemical properties of IRDCs, we have undertaken a molecular line survey of the star/cluster forming clumps MM1, MM4, and MM9 in IRDC G28.34+0.06 at the 3mm atmospheric window utilizing the Nobeyama Radio Observatory 45M Telescope. The survey has achieved a frequency coverage from 86 GHz to 98 GHz at a rms noise level of $\sim$ 5 mK. Additional coverage over the 3mm window as well as selected lines/frequencies at 40 GHz was also obtained. Distinctively different spectral signatures are found among these clumps, signifying their different physical and chemical properties likely related to the evolutionary stages. For example, hot core tracers are clearly found in MM1, where 30 some species have been detected. MM4 also harbors hot core(s) as indicated by the detection of, for example, CH_3CN, CH_3OH and CH_3CHO, although the gas temperature derived from the CH_3CN J=5-4 lines is noticeably cooler ($\leq$30 K) than that in MM1 ($\sim$50 K). The highest values of [CCS]/[N_2H^+] and the lack of hot core signature of MM9 mark its cold and early stage in evolution.

P63

Testing the formation scenario of massive star by CH3OH maser

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Now classI CH3OH maser is thought to be associated with outflow, while classⅡ CH3OH maser is thought to be associated with accretion disc. If this is true, class CH3OH maser is expected to be distributed perpendicularly with respect to rotating disk. Detecting (or rejecting) this will play a major role in understanding the scenario of massive star formation. To do this, we plan to observe distributions of two classes of CH3OH masers with VLBI.
For that purpose, first we have to look for target sources in which both of classes are detected. We performed the single-dish observations of both classes of CH3OH maser using Nobeyama 45m and Yamaguchi 32m telescopes. As a result, we discovered 70 sources detected in both classes. Spectra of some of sources that both classes were detected are shown in Figure 1.

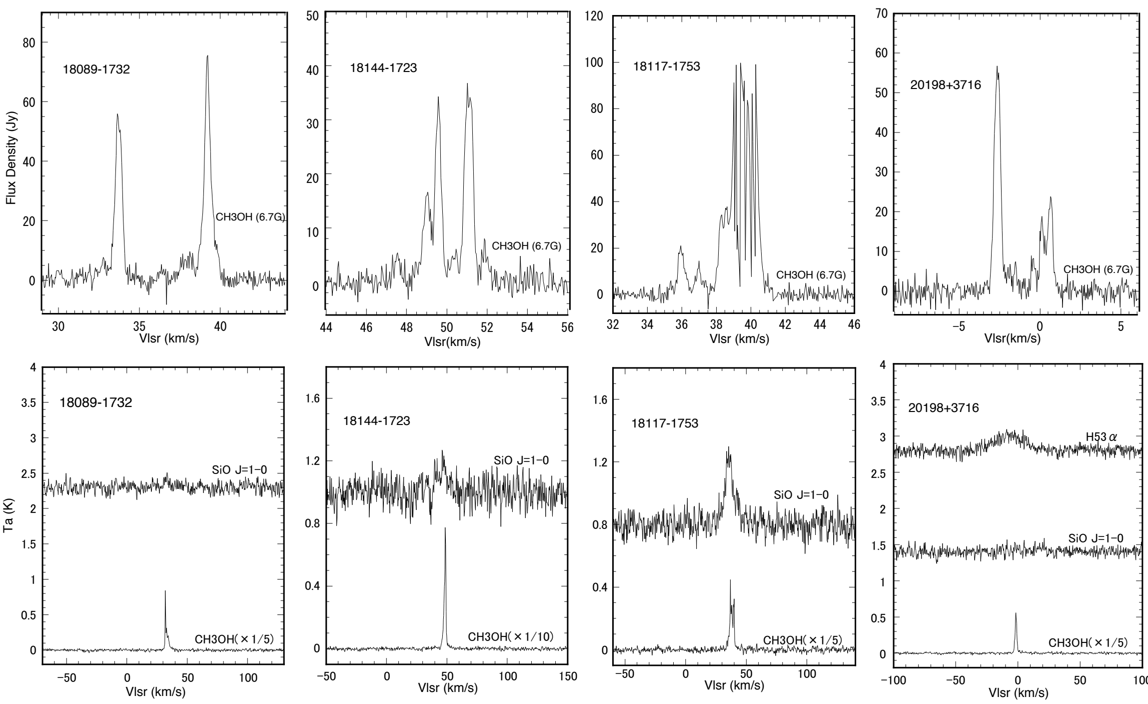

Figure 1: The spectra of the sources in both of classes were detected.

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Multi-Phase Dynamics of Magnetized Interstellar Medium

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The recent progress in our understanding of the dynamics of multi-phase interstellar medium (ISM) is dramatical. ALMA may provide an opportunity to open a new era for the investigation of cold, warm, and non-thermal components of interstellar medium. Non-linear perturbations (e.g., shock waves or time-dependent radiation field) lead to the interchange between warm phase and cold phase via thermal instability. Dynamical modelling of the phase transition dynamics is essential in describing ubiquitous turbulence in ISM and the formation of molecular clouds. A concept of magnetically multi-phase medium is also introduced. Recent finding of the magnetic field amplification in the blast wave propagating in magnetized multi-phase ISM is providing an interesting scenario for rapid acceleration of cosmic rays.

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P65

Chemical Compositions of Massive Clumps in Early Evolutionary Stages of High-mass Star Formation

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We report how the chemical composition changes with the evolution of massive clumps. It has well been established that chemical composition is a useful indicator of evolutionary stages for low-mass starless cores. We considered that such a chemical approach would also be useful for high-mass sources, and carried out systematic surveys of several molecular lines toward massive clumps, which includes infrared dark clouds (IRDCs) and high-mass protostellar objects (HMPOs). We found that the CCS/N_2H^+ ratio of massive clumps is lower than that of young low-mass starless cores. This indicates that most of the massive clumps are chemically evolved than the young low-mass starless cores, since the CCS/N_2H^+ ratio is known to become lower for more evolved cores. In addition, we found that the SiO and CH_3OH abundances relative to $H^{13}CO^+$ are enhanced in several massive clumps. Since SiO and CH_3OH are known as shock tracers, these results suggest that the effect of shocks is more significant in the IRDCs than in the HMPOs. Such shocks would be caused by an interaction between outflows and dense gas. Furthermore, the DNC/HNC ratio was found to be lower toward massive clumps than low-mass cores, and that some IRDCs have a lower DNC/HNC ratio than the HMPOs, although the gas kinetic temperature of the IRDCs is lower than that of the HMPOs. These trends cannot be explained by the difference in the current temperature. Rather, these trends seem to reflect the difference in the initial DNC/HNC ratio before the onset of star formation. In this poster, we compare the observation results with the model calculation results, and discuss how the deuterium fractionation ratios vary after the onset of star formation.

In addition to the above results, we report the current status of the receivers on the NRO 45 m telescope (70 GHz Rx. and 140 GHz Rx.) and on the ASTE 10 m telescope (350 GHz Rx. and 500 GHz Rx.).

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Water Vapor Masers in the NGC7538 Region

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The NGC7538 region is one of the active massive star-forming regions in Perseus arm. There are at least three active star forming areas, IRS1-3, IRS9, and IRS11, in the NGC7538 molecular cloud. Multi-epoch 2 beam VLBI observations towards them have been performed by using the VERA in order to find detailed distribution and motion of water vapor masers in three areas. Some results of the distribution/motion of them are shown and the comparison with those of the other activities (IR sources, outflows, Ultra-compact HII regions, the other masers, etc) in three areas are discussed.

P67

Discovery of the rotating molecular outflow and disk in the Class-0/I protostar [BHB2007]#11 in Pipe

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The loss of angular momentum is inevitable in star formation processes, and a transportation of angular momentum by a molecular outflow is widely thought to play a important role. The driving mechanisms of molecular outflows, however, have not been well understood yet. One possible approach is to detect rotational motion of molecular outflows since outflows are considered to transfer specific angular momentum from circumstellar disks.

We present the results of 1″ resolution Submillimeter Array (SMA) observations in 1.3 mm dust continuum, CO(2–1), ^{13}CO(2–1), and C^{18}O(2–1) emissions toward the low-mass Class-0/I protostar, [BHB2007]#11 (hereafter, B59#11) at the nearby star forming region, Barnard 59 (B59) in the Pipe Nebula ($d = 130$ pc ; Lombardi et al. 2006). B59#11 ejects a molecular outflow toward the plane of the sky direction (Duarte et al. 2012), and considered to have an edge-on disk. It is also the brightest 1.1 mm source among protostars in the AzTEC/ASTE survey of low-mass star forming regions (Kawabe et al. in prep).

From ^{13}CO(2–1) and C^{18}O(2–1) observations, it has been revealed that the dense gas is elongated along NW-SE direction (Fig. 1 (b) and (c)), which is the perpendicular direction to that of the molecular outflow identified with single-dish observations, and show velocity gradients along the elongations. The radial velocity in C^{18}O(2–1) emission shows the power-law profile ($v \propto r^{-\alpha}$) and the power-law index, α ∼-1/2, suggesting that C^{18}O(2–1) emission traces the rotationally supported disk with a size of ∼300 AU.

The results of observations in CO(2–1) emission have revealed that the velocity gradient exists in the outflow (Fig.1 (a)) along the same direction as rotation of the disk and/or envelope. These results suggest that the outflow is rotating. It may be the first detection of the rotation of the outflow associated with protostars in main accretion phases in CO emission. The specific angular momentum of the outflow, ∼2.0×10^{-3} km/s pc is almost consistent with that of the envelope.

We propose that the outflow is ejected from the edge of the disk, i.e., ∼300 AU scale region. ALMA will give us an excellent opportunity to unveil the lunching point of the molecular outflow associated with B59#11 and to pin down the driving mechanism.

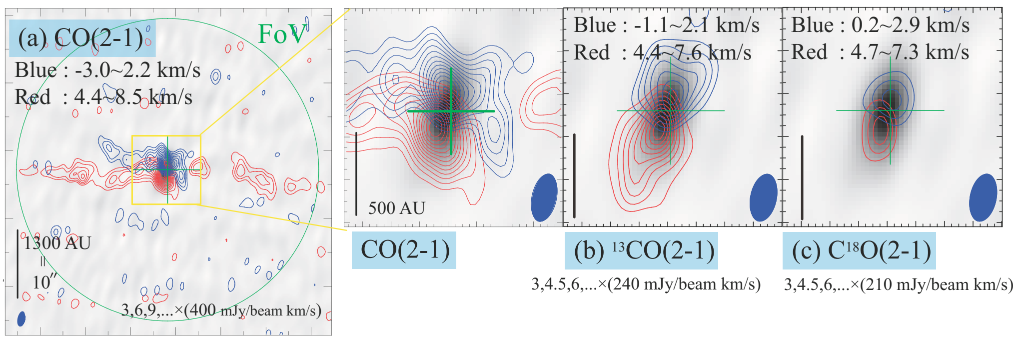

Fig. 1 : (a) High velocity components in the SMA CO(2–1) emission. (b) (c) High velocity components in the SMA ^{13}CO(2–1) and C^{18}O(2–1) emission, respectively. Gray scales are the 1.3 mm dust continuum maps.

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P68

CO line observations in the L1551 Cloud with the Nobeyama 45 m Telescope

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We have carried out mapping observations of the entire L1551 molecular cloud with about 2 pc $\times$ 2 pc size in the ^{12}CO, ^{13}CO and C^{18}O (1-0) line with the Nobeyama 45 m radio telescope at the high effective resolution of 22" (corresponding to 0.017 pc at the distance of 160 pc).

We derived the new non-thermal line width-size relations, $\sigma_{\rm NT} \propto L^{\gamma}$, for the three molecular lines, corrected for the effect of optical depth and the line-of-sight integration. To investigate the characteristic of the intrinsic turbulence, the effects of the outflows were removed. The derived relations are ($\sigma_{\rm NT}$ $\rm km\ s^{-1}$) = (0.18 $\pm$ 0.010)(L/pc)0.45 0.095, (0.20 $\pm$ 0.020)(L/pc)0.48 $\pm$ 0.091, and (0.22 $\pm$ 0.050) (L/pc)0.54 $\pm$ 0.21 for the ^{12}CO, ^{13}CO, and C^{18}Olines, respectively, suggesting that the line width-size relation of the turbulence very weakly depends on our observed molecular lines, i.e., the relation does not change between the density ranges of 10^{2-3} and $10^{3-4}\rm cm^{-3}$. In addition, the relations indicate that incompressible turbulence is dominant at the scales smaller than 0.6 pc in L1551. The power spectrum indices converted from the relations, however, seem to be larger than that of the Kolmogorov spectrum for incompressible flow. The disagreement could be explained by the anisotropy in the turbulent velocity field in L1551, as expected in MHD turbulence. Actually, the autocorrelation functions of the centroid velocity fluctuations show larger correlation along the direction of the magnetic field measured for the whole Taurus cloud, which is consistent with the results of numerical simulations for incompressible MHD flow.

In addition, we identified ^{13}CO and C^{18}O cores by the clumpfind algorithms. For the C^{18}O cores, the mean radius, velocity width, LTE mass, and number density of the cores are 0.049 $\times$ 0.008 pc, 0.35 $\pm$ 0.07 $\rm km\ s^{-1}$, 0.89 $\pm$ 0.62 $M_{\odot}$, and (2.9 $\pm$ 1.2) $\times 10^4 \rm cm^{-3}$, respectively, and the cores are likely to be gravitationally bound by considering the uncertainty in the C^{18}O abundance. We derived a C^{18}O core mass function (CMF), which shows a power-law like behavior above 0.6 $M_{\odot}$. The best-fit power-law index of —2.3 $\pm$ 0.2 is consistent with those of the dense core mass functions and the stellar initial mass function (IMF) previously derived. This agreement strongly suggests that the power-law form of the IMF has been already determined at the density of $10^4 \rm cm^{-4}$, traced by the C^{18}O (J=1-0) line.

For the ^{13}CO cores, the mean radius, velocity width, LTE mass, and number density of the clumps are 0.031$\pm$0.006 pc, 0.47$\pm$0.09 $\rm km\ s^{-1}$, 0.11$\pm$0.11 $M_{\odot}$, and (2.0$\pm$2.3)$\times 10^4$ cm^{-3}, respectively, and the clumps are likely gravitationally unbound. By comparing the ^{13}CO clumps with the C^{18}O cores, we found that 177 clumps are associated with 36 cores and the other clumps have no counterparts. In addition, We derived a ^{13}CO clump mass function (CMF), which shows a power-law-like behavior above a turnover at 0.06 $M_{\odot}$. The best-fit power-law index γ of -2.2$\pm$0.2 is quite consistent with those of the dense core mass functions and the stellar initial mass function (IMF) previously derived. We derived the two CMFs of the ^{13}CO cores with higher and lower densities than 10^4 cm^{-3}, and found that the γ value of 2.0 $\pm$ 0.07 for the higher density clumps is consistent with the IMF, while the index of 4.0 $\pm$ 0.27 for the lower density clumps is considerably larger than that of IMF. From these facts, we conclude that the index of clump mass function changes at 10^4 cm^{-3}. Below 10^4 cm^{-3}, the index of the clump mass function is different from that of IMF. Above 10^4 cm^{-3}, the γ of the unbound ^{13}CO clump mass function is consistent with that of the bound C^{18}O core mass function.

P69

Mapping Observation toward Protostellar Core L1527

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We observed molecular line emission toward a low-mass protostellar core L1527 in the Taurus Molecular Cloud at a distance of 140 pc with the Nobeyama 45 m telescope to reveal the velocity structure closely related to the evolution of star formation.

Recently, it has been obtained that fairly detailed information of the internal mass distribution of a molecular cloud core from the dust millimeter and submillimeter continuum observations. On the other hand, we have not yet fully understood the motion of the circumstellar gas, in particular about the origin of angular momentum distribution. In star formation, the distribution of angular momentum at the early phase is a crucial parameter to determine the evolution such as binary formation and disk formation. Since there is a large gap of the specific angular momentum between a molecular cloud core and a star/disk system, the surplus angular momentum have to be converted to orbital angular momentum of a binary or have to be removed by the jet/out flow with the interaction of the magnetic field.

Several surveys in the past the angular momentum in dense cores have been conducted so far, such as Goodman+(1993), Ohashi+(1997), Caselli+(2002), and Tobin+(2011). These studies, however, have not revealed the radial distribution of the specific angular momentum because it is assumed a rigid rotation velocity gradient in the dense core. One such exception is Belloch+(2002) which demonstrated a differential rotation in the envelope and core. There are some objects, which can approximate a nearly rigid rotation since the core velocity gradient is perpendicular to the molecular flow, such as B335. On the other hand, objects, in which the velocity gradient in a dense core scale is nearly 45 degrees respect to the direction of the molecular flow, have been found, for example L1527. These differences will be dependent on the origin of the angular momentum of the molecular cloud core.

Taking these situation into account, we observed 6'x6' OTF (On the Fly) mapping in $^{13}CO/C^{18}O$ with 0.1 km/s resolution toward protostellar core L1527 using T100H/V receiver in Nobeyama 45m Telescope. Mapping area covers the dense core on a scale of about 0.2pc.

Here we report the preliminary result of $C^{18}O$ observations. In the integrated intensity map, the emission distribution is concentrated on the protostar. In the 1st moment map, there is a the velocity gradient from the northwest to southeast. In the 2nd moment map, interestingly there is a trend of increasing the velocity dispersion in the direction of the outflow direction.

The trend in the 2nd moment map of $C^{18}O$ may be discovered for the first time, and is related to the mechanism of losing the initial molecular cloud core. In the future work, we need high resolution observations to determine the velocity structure from dense core scale to disk scale..

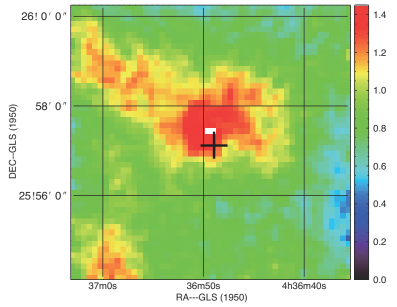

Figure ; The integrated intensity map for $C^{18}O$. Cross marks the position of protostar IRAS04368+2557.

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P70

A study on the excitation mechanism of methyl formate in Orion KL by using transitions in the vibrational excited states

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The methyl formate ($HCOOCH_3$) is a well-known interstellar molecule almost ubiquitously found in the star-forming regions. The spectrum of this molecule is very dense for two reasons: (1) The spectra split into two symmetry species A and E due to a methyl internal rotation which is equivalent to the torsional vibration (we use abbreviation of vt to represent this vibration). (2) The fundamental frequency of this torsion is only ca. 135 cm^{-1} so that the transitions in the excited states significantly appear. This small excitation energy suggests plausible detection of methyl formate in the torsional excited states in space. Indeed we reported the identification of methyl formate in the first excited state in Orion Kleinmann-Low (KL) (Kobayashi et al. 2007). Demyk reported its observation in W51 e2 (Demyk et al. 2008). The relatively strong signal of methyl formate in the excited state prompted us to search for the methyl formate in the second torsional excited state.

Therefore we have carried out an observation on a series of transitions in the torsional excited state from vt = 0, 1, 2 of methyl formate toward Orion Kleinmann-Low(KL) with the Nobeyama 45m radiotelescope. The laboratory rest frequencies of the methyl formate in the second torsional state were observed at the University of Toyama (K. Kobayashi in preparation). The transitions in vt=2 was observed successfully as well as vt = 0 and 1 (Takano et al. 2012). The column densities and temperatures were obtained by the use of a conventional rotation diagram.

By considering the each torsional state is a single state, the column density in vt=2 was determined to be $(3.0 \pm 1.5) \times 10^{14}$ cm^{-2}. The obtained rotational temperatures and the column densities for the vt = 0 and 1 states are 43 ± 9 K and $(3.8 \pm 1.2) \times 10^{15}$ cm^{-2}, and 53 ± 8 K, $(9.8 \pm 2.3) \times 10^{14}$ cm^{-2} respectively. The column densities in vt = 0 and 1 are factors of 13 and 3 larger than that in vt = 2. When the data are treated all together, the data of these three states can be explained by a single vibrational temperature of 124 ± 5 K, which is significantly higher than the rotational temperatures. As excitation mechanisms of this torsion, there are two possibilities, collision with H_2 and pumping by FIR radiation. Considering the temperature difference and Einstein's A coefficients of the torsional states, we cannot rule out either of these mechanisms. The present results further indicate that many more unidentified lines in Orion KL will be due to low-lying excited states of methyl formate and other organic molecules. The observation of the molecules in the vibrational excited states could be a good tool to explore the excitation mechanism. Close collaboration between radio observation and laboratory spectroscopy will be important for studying the nature of such lines in order to understand the physical and chemical conditions, and for finding new molecules.

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P71

Molecular Emission Observations of Starless Cores on the Brink

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We intend to constrain through observations the physical state of cores that are on the brink of star formation. Accordingly we have observed six suitable candidates of dense cores selected from current surveys of nearby molecular clouds in molecular emission that trace well the temperatures, densities, and dynamics of the cores, such as N_2H^+ and NH_3 using single dish telescopes and interferometers. Here, we present the single dish data and analysis of N_2H^+ $(1-0)$ and NH_3 (1,1) and (2,2) emission toward L1689-SMM16, a starless core in Ophiuchus molecular cloud, acquired using Nobeyama Radio Observatory (NRO) and Green Bank Telescope (GBT).

P72

New detection of an extremely blue-shift dominated jet in G353.273+0.641: A possible disk-jet system on 100 au scale

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We report a new detection of an unusual molecular jet from a high mass protostellar jet G353.273+0.641 (G353). The target source, G353, is known as a highly blue-shift dominated 22 GHz H_2O maser source. This type of a maser source is called dominant blue-shifted maser (DBSM) and a candidate of a high mass protostellar object with nearly pole-on disk-jet system. Our VLBI-monitoring project with the VERA has revealed highly variable maser activities. All maser spots are, in addition, located on the root of a radio jet detected by the ATCA, suggesting a presence of an episodic and compact molecular jet enclosed by the radio jet. Our follow-up molecular jet survey using the NRO 45m telescope has found an extremely high-velocity (EHV) and unusually broad SiO ($\upsilon = 0$, $J = 2$–1) emission. It shows quite similar blue-shift dominated spectrum as the maser (see Figure 1). This spectral similarity strongly suggests that this EHV SiO jet is directly related to the maser excitation. If this is the case, an expected scale of the SiO jet can be comparable with the maser distribution i.e., only $0''.1$ ($\sim$ 170 au).

The remarkable blue-shift dominance in both of the maser and SiO (2–1) line cannot be explained by an asymmetric jet structure for the following reasons, (1) An associated radio jet of $1''$ scale shows a clear bipolar structure, (2) A statistical anomaly was reported, where a number of DBSM is far larger than that of a red-shifted dominated maser source. The latter indicates that some intrinsic mechanism is required to cause strong blue-shift dominance. The most plausible scenario is that a red-shifted side is masked by a disk that is optically thick at 22 and 86 GHz. Such an optically thick disk has actually been reported in several high and low mass YSOs. An expected disk size is smaller than $0''.1$ for both of a dust-dominated and free-free dominated disk, and hence, enough to cause significant masking to the red-shifted side of a maser-scale jet. If our scenario is true, such a compact disk-jet system will fill in a spatial missing-rink between non-thermal maser study with VLBI and thermal study with the ALMA.

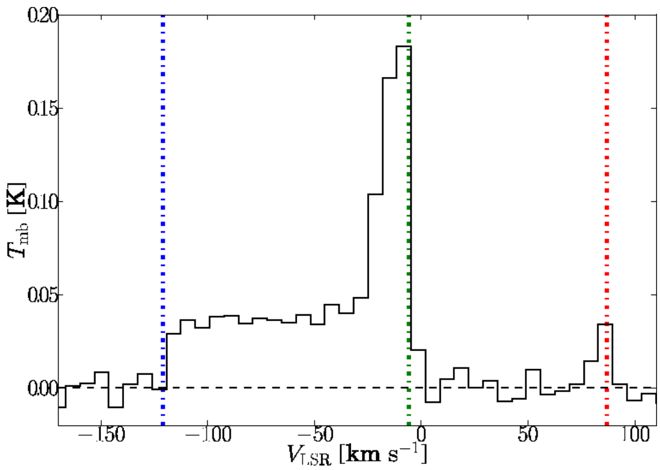

Figure 1: The SiO ($\upsilon = 0$, $J = 2$–1) spectrum taken by NRO 45m in $T_{\rm mb}$ scale. The blue and red dotted line indicates the most red (+87 km s^{-1}) and blue-shifted (-120 km s^{-1}) maser component, respectively. The systemic velocity of -5 km s^{-1} is also indicated by the green dotted line. The black horizontal line shows zero level.

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P73

Millimeter-Wave Band Monitoring Observations of Solar System Planetary Atmospheres with an Exclusive Ground-Based 10m-Telescope for SPART Project

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It is well known that solar activities such as solar winds, solar flares, solar proton events (SPEs) have affected the environments and evolutions of planetary atmospheres. To further understand the habitable zone and atmospheric chemistry, dynamics, temperature of solar and extra-solar planets, it is important to study the influence of activities of our Sun, which is a typical G-type star, on the atmospheres of Venus and Mars as well as of Earth. The Earth is protected by its geomagnetic field, whereas Mars and Venus are directly exposed to solar activities because of the absence of such an intrinsic geomagnetic field. Unfortunately, there is a lack of observations and theoretical and systematical simulations to study how energetic particles and radiation induced by solar events affect the middle atmospheres.

In order to investigate the relationship between solar activities and variabilities in the atmospheric conditions and climates of solar planets we started a long-term and regular monitoring observation project, SPART (solar planetary atmosphere research telescope), in 2011 by launching a purpose-built ground-based single dish 10m-telescope. This is the utilization of the heritage of the Nobeyama Millimeter Array. 100 and 200 GHz band superconductor-insulator-superconductor receivers with quantum limited noise performance are employed for the front-end. We installed a field programmable gate array (FPGA) based commercial Fast Fourier Transform Spectrometer (FFTS) with the frequency resolution of 61 kHz and the bandwidth of 1 GHz newly for the back-end.

The middle atmosphere, which plays an important role in controlling the atmospheric environment of a planet, is considered to be sensitive to solar activities because of its moderately low density and the formations of chemically active species. One of the best probes to study time-dependent physical and chemical conditions in Mars and Venus's middle atmosphere is the rotational spectral lines of carbon monoxide (CO). CO_2 is the main component in Mars and Venus's atmosphere. CO is formed from CO_2 basically by a photo-dissociation process owing to solar UV radiation. Mm/submm wavelengths heterodyne spectroscopies with high-frequency resolution allow us to derive the vertical distribution of CO and/or temperature of the middle atmosphere through retrieval analysis.

In this conference we will present the CO absorption spectra observed regularly toward Mars and Venus in 2012 and the current status of the SPART project.

P74

Water Masers Tracing a Circumstellar Disk toward IRAS 23033+5951

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We present water maser observations toward IRAS 23033+5951 carried out with the VLA-EVLA in the A configuration. In order to study the spatio-kinematical distribution of the water masers detected in the region, we made a simple geometrical and kinematical model based on the conical equation. We find that the water masers are tracing a rotating and contracting circumstellar disk of about 110 AU around a very young source of 18 $M_\odot$, which has not enough ionizing photons to be detected at centimeter wavelengths.

P75

Deuterated Water in Turbulent Protoplanetary Disks

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Deuterated water observed in the current solar nebula can provide insights into how water has evolved in the primitive solar nebula. So far, D/H ratios in cometary water have been measured in seven comets, six from the Oort Cloud ($\sim$(3–5)$\times 10^{-4}$; e.g., Mumma et al. 2011, and references therein), one from the Kuiper Belt ($\sim 1.6\times 10^{-4}$; Hartogh et al. 2011). In all of them, deuterium concentrates by about an order of magnitude relative to the elemental abundance of deuterium in the interstellar medium ($\sim 1.5\times 10^{-5}$; Linsky 2003). A key question is when this ratio is established during the star and planet formations. Here, we focus on the protoplanetary disk phase.

Deuterium fractionation in plotoplanetary disks have been studied numerically (e.g., Aikawa & Herbst 1999). Willacy et al. (2009) investigated deuterium chemistry in inner disks ($\lesssim$30 AU) considering the radial accretion. They found that the D/H ratio in water ice in the midplane retains their initial ratio ($\sim 2 \times 10^{-2}$, which set by their dense cloud core model) for 10^6 yr, since water ice is not destroyed efficiently there. However, we note that turbulent mixing could change the situation drastically. Oxygen is mainly in atomic form in the disk atmosphere, while it is in water ice in the midplane (e.g., Bergin et al. 2007, and references therein). If the turbulence exists, water ice would be transported to the disk atmosphere and destroyed by photoreactions and/or thermal desorption, while atomic oxygen would be transported to the disk midplane and reform water ice. If such destruction and reformation processes occur effectively, the D/H ratio in water ice would be lowered or enhanced depending on the atomic D/H ratio near the disk midplane. Since Willacy et al. (2009) showed the atomic D/H ratio in the disk midplane is about $\sim 10^{-4}$ at warm temperature at $R \sim 10$ AU, the mechanism is of potentially importance for the D/H ratio of water in the solar nebula.

In this presentation, we report the effect of turbulent mixing in the vertical direction on the D/H ratio of water in protoplanetary disks. We solved the rate equations with diffusion terms, which mimic the turbulent mixing, adopting the physical model of a disk surrounding a typical T Tauri star (Nomura et al. 2005, 2007). A collapsing core model is calculated to set the initial molecular abundances of our disk models, in which the D/H ratio in water ice is $\sim 10^{-2}$. The D/H ratio in water ice in the midplane does not significantly change for 10^6 yr in the case of α of 10^{-3}, while it decreases to $\sim 10^{-3}$ at $R \sim$ 10–30 AU in the case of α of 10^{-2}. The model ratio remains higher than the cometary ratio. It indicates that in the case of the solar nebula, the D/H ratio in water might be already much less than 10^{-2} in the early phase of the disk.

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P76

Molecular Evolution in the First Hydrostatic Core Phase Adapting Three-Dimensional Radiation Hydrodynamic Simulations

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First hydrostatic cores are key objects to understand star formation processes; they fragment and form binaries (Matsumoto & Hanawa 2003), drive bipolar molecular outflows (Tomisaka 2002), and their outer regions might directly evolve to circumstellar disks, while the central regions collapse to form protostars (Machida et al. 2010; Bate 2010). While their dynamical evolutions have been well studied, their chemical compositions remain unrevealed. Unveiling chemistry in the first core stages is important; (i) to find observational tracers (ii) to reveal the initial compositions of circumstellar disks.

In this presentation, we report the molecular evolution that develops as star formation proceeds from molecular cloud cores to the first hydrostatic cores in three spatial dimensions. We performed radiation hydrodynamics simulations (Tomida et al. 2010) in order to trace fluid parcels, in which molecular evolution is investigated, using a gas-phase and grain-surface reaction network model. We derived the spatial distributions of molecular abundances and column densities in the cloud core harboring the first cores. We found that the total of gas and ice abundances of many species are set in cold regions (10 K), and remain unaltered until the temperature reaches ∼500 K. Then the gas abundances in the warm envelope and outer layers of the first core ($T < 500$ K) are mainly determined via the sublimation of ice-mantle species. Above 500 K, the abundant molecules start to be destroyed mainly via collisional dissociation, and simple molecules, such as CO, H_2O and N_2 are reformed. On the other hand, some molecules are effectively formed at high temperature; carbon-chains, such as C_2H_2 and cyanopolyynes, are formed at the temperature of >700 K. We also found that large organic molecules, such as CH_3OH and $HCOOCH_3$, are associated with the first core ($r < 10$ AU). We propose that these large organic molecules can be good tracers of the first cores.

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P77

The temperature and surface density structures of a typical full disk around MWC 480

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With the recent advent of improved observational equipment and facilities, the observation of diffused gas near outer edge of the protoplanetary disk that used to be very difficult to observe has recently become possible. We made multi-CO line observations toward a well-known protoplanetary disk around MWC 480 (HD 31648), in millimeter, ^{12}CO (J=1–0), ^{13}CO (J=1–0), and C^{18}O (J=1–0), and sub-millimeter wavelengths, ^{12}CO (J=3–2) and ^{13}CO (J=3–2), by Nobeyama Radio Observatory (NRO) 45 m telescope and ASTE (Atacama Submillimeter Telescope Experiment) 10 m telescope, and derive the temperature and the surface density structures of the disk in radial and vertical directions. The emission from the tenuous gas in the outer disk that makes a peak-to-peak velocity width narrower was detected in the optically thicker line, whereas the emission from the dense inner disk that makes the width wider was detected in the optically thiner line, due to Keplerian rotation.

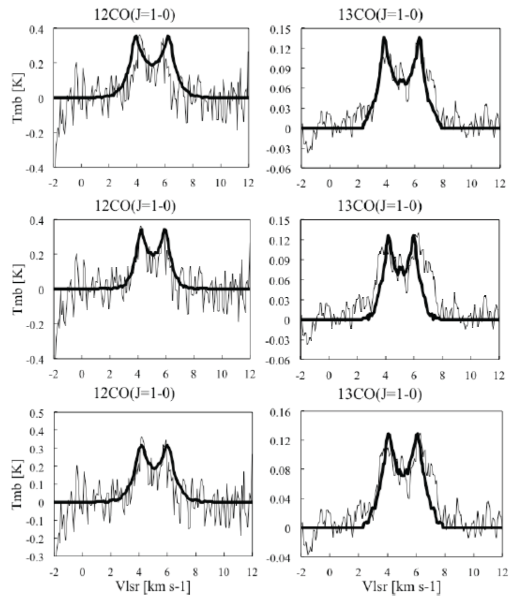

Figure 1: Comparison among model fitting results. Fitting by power-law model in the case of ^{13}CO (J=1–0) best fitting (top), fitting by power-law model in the case of ^{12}CO (J=1–0) best fitting (middle), and the best fitting by similarity solution model (bottom). Thin lines show the observed spectra and Thick lines show the profiles calculated by models.

Using data from the NRO 45 m and ASTE telescopes, we show a better description motivated by similarity solutions of viscous evolution of accretion disks that has an exponentially tapered outer edge was applied to model fitting, rather than a common model described by power laws in temperature and surface density with truncation at a particular outer radius. Figure 1 shows the comparison of fitting results between power-law and similarity solution models. The observation can be reproduced in a single set of parameters by similarity solution model, while power-law model can not. It indicates that the disk gas extends and gradually tapers off. The fitting in molecular emission lines only by similarity solution model is first attempt and the results are consistent with the ones obtained by combination of dust continuum and molecular emission lines, including the other star+disk systems, such as HD 163296 and GM Aurigae. Although it requires further validation, it seems that the tapered outer edge structure is ubiquitous in protoplanetary disks.

We also show vertical temperature distribution in the disk. As a result of integrating the fitting temperatures and vertical depth of photospheres of each CO emission by taking advantage of different mass opacities (κ_ν), and therefore their optical depths, there must exist at least two different temperature regions in the disk 100 AU away from the central star; colder interior and warmer upper surface of the disk. This kind of picture is consistent with the passive disk characteristic predicted by the disk theory.

P78

A Search for Water Masers in Icy Bodies of the Solar System

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Maser phenomena are widely observed in celestial objects. Dense cores of molecular clouds and circumstellar envelopes of late-type stars are typical examples of such maser sources. These masers have been used as probes of gases with the H_2 number density of typically 10^4-10^{10} cm^{-3}. While maser and laser phenomena (OH, H_2O, CO_2) have been observed in some solar system objects, H_2O maser was reported only for the catastrophic impact of comet Shoemaker-Levy 9 and Jupiter [1].

A recent report showed that H_2O maser phenomena was found in the system of Saturnian moons [2]. The report showed that water maser emissions at 22.235 GHz were seen from the vicinities of Titan, Hyperion, Enceladus and most notably Atlas. The observations were conducted with the Medicina 32 m and Metsahovi 14 m telescopes. In May 2009, we tried to detect the maser emission from several Saturnian moons with the Nobeyama 45 m radio telescope [3]. Observations were carried out for Titan, Hyperion, Enceladus and Atlas, in which detections were reported previously [2], and in addition for Iapetus and other inner satellites. However, we could not detect any water maser emission in all the listed sources. The typical daily observing sensitivity of these results ($3\sigma \sim$ 200-700 mJy) was comparable to, or even better than those of the previous studies.

In 2011, we have repeated the observations for Saturnian system with the same sensitivity. We also attempted to detect the water maser line from other Kuiper-belt objects in the Solar System (Makemake, Haumea, and Varuna).

At this conference, we report the results of the 2009 and 2011 observations. Although we are not in the position to confirem earlier detections, our new results would offer the clue on hypothetic water maser phenomena, and would give us the hints of maser emission mechanism.

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P79

Near-infrared imaging observations of circumstellar disk around HD 169142 with Subaru/HiCIAO

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HD 169142 is a Herbig Ae star (A8 Ve) located at a distance of 145 pc from the Sun[1]. Interferometric observations at millimeter and submillimeter wavelengths revealed a circumstellar disk around HD 169142, with the radius of $1.4''(\approx 200\mathrm{AU})$ and with its inclination angle of 13° [2,3]. Near-infrared imaging with the HST coronagraph also detected scattered light with similar size[1]. The amount of excess emission at mid-infrared wavelengths is small, suggesting that the outer disk is truncated at $\sim 0.15''$ ($\sim$ 20AU) from the star [4,5]. We carried out polarization differential imaging (PDI) of the disk scattered light in H-band with HiCIAO + AO188 installed in Subaru Telescope.

Figure 1 shows the obtained polarized intensity (PI) image. Significant scattered light is detected in the regions of $0.2'' - 1''$ in radius. There is a gap between $0.35'' - 0.6''$. Azimuthally-averaged radial profile of PI in the inner ($r < 0.35''$) or outer ($r > 0.6''$) regions can be fitted well with a power-law of r^{-2}, but that between these two regions (i.e., gap) is almost flat. Non-axisymmetric pattern of surface brightness can also be identified in the PI image. At $r \approx 0.25''$, for example, the northwestern part (PA=5° $-$ 275°) is much brighter than the southeastern part (PA=95° $-$ 185°). The opposite trend, however, is found at $r \approx 0.55''$.

Several mechanisms can produce the inner cutoff of the disk. Grady et al. (2007) [1] discussed in detail the two possibilities: (i) photoevaporation of the inner regions, and (ii) dynamical effect by an unseen non-stellar companion. Compared to the latter mechanism, the former mechanism can hardly produce non-axisymmetric pattern like that seen in our PI image (Figure 1). We therefore consider that our results strongly suggest the existence of a substellar companion, presumably in $r < 20$AU or in the gap ($39 - 65$ AU).

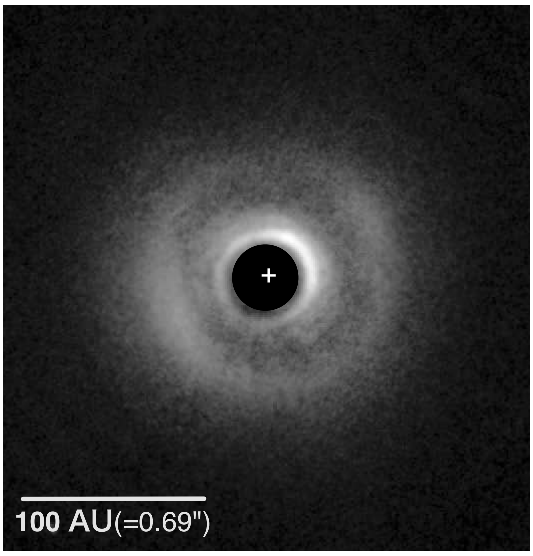

Figure 1: PI image with HiCIAO. Black area and white cross indicate the masked region and stellar position, respectively.

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P80

Submillimeter and Near Infrared Studies for the Extreme Transition Disk around Sz 91

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Transition disk objects are categorized as young stars with little or no near infrared (NIR) excess and significant far infrared (FIR) excess in their SED, implying that inner gaps of the surface density distribution of their circumstellar disk. Several mechanisms to form the gap features have been proposed: photo-evaporation by the central star[4], grain growth at the inner disk[6], and dynamical interaction with (sub-)stellar companions[5]. Since the (sub-)stellar companions, like giant planets, are one of the most exciting explanations, the transition disk objects are important targets to investigate planet formation process as well as disk evolution.

Sz 91 is a M0.5 star with a transition disk at the Lupus molecular cloud ($d = 200$ pc). The spectacular feature of this source appears in the SED: there is no NIR excess from K_s to 24 μm (i.e., class III of IR category), a large dip around 20 μm, and a steeply rising slope between 24 and 70 μm[8]. Recently, Romero et al. (2012)[8] categorized Sz 91 as a giant planet-forming disk by the following reasons: the sharp inner hole edge which is indicated by the sharp rising at 24 μm, the clear sign of accretion with a Hα equivalent width at 10 % of 283 Å, and the relatively massive disk. However, an actual disk structure was not revealed yet.

To reveal structures and kinematics of this transition disk and the surrounding environment around Sz 91, we performed 1.1 mm continuum photometry and multi-line spectroscopy at 345 GHz with Atacama Submillimeter Telescope Experiment (ASTE) and high-resolution imaging with Submillimeter Array (SMA). Our results strongly support that Sz 91 is most likely to possess the transition disk in the evolutional stage at the planet formation as follows.

We detected point-like 1.1 mm emission at the stellar position with a flux of 27.2 mJy, corresponding to a gas mass of $\sim 10^{-3}$ $M_\odot$ if the gas-to-dust ratio is assumed to be 100:1. The derived mass was higher than other class III sources in the nearby star forming regions[1,2], but the one of the lightest dust disks among transition disks[3]. This rare sample was one of three sources with a detectable 1.1 mm emission among 214 class III sources in the surveyed region, indicating that time scale of such an evolutional phase is as short as $\sim 10^4$–10^5 yr. The spatial 5-points spectra in CO(3–2) and ^{13}CO(3–2) obtained with ASTE indicated that Sz 91 is still surrounded by the ambient cloud.

Our 345 GHz continuum images revealed the circumstellar transition disk with a radius of $R_{\rm out} = 170$ AU and the possible inner hole structure with $R_{\rm in} < 87$ AU. The depletion factor at the inner hole was poorly constrained to be greater than ~ 3. Our high-resolution image of polarized intensity at *H*-band with Subaru Telescope revealed the faint scattered disk near the star. This scattered disk distributed in the dust depleted region seen in 345 GHz, implying that small grains still remain in this region. This fact is consistent with the filtering effect of dust grain by planet formation in the disk[9]. Significant CO(3–2) emission was also detected, and we found the velocity gradient along the NE to SW. The spectral profile of CO(3–2) was double-peaked, indicating the existence of a keplerian rotating gas disk. Although Sz 91 has no significant NIR excess, a large amount of gas remains in the disk as well as dust.

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P81

The influences of disk winds on chemical evolution of plotoplanetary disks

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In the past 20 years, several molecules, molecular ions and radicals have been detected from plotoplanetary disks thanks to the improvement of observational facilities. More species will be observed by ALMA which has high sensitivity and spatial resolution. So, theoretical study of chemical structure of plotoplanetary disks is required, in order to understand detailed chemical and physical structure of the disks from the detected molecular lines.

In this study, we calculate the chemical evolution of plotoplanetary disks considering disk winds driven by MRI turbulence and investigate the influences of disk winds on chemical structure of disks. As a result of our calculations, abundances of some molecules increase at the boundary between intermediate and upper layers. It is because molecular hydrogen is transferred into hot layer where molecules such as OH, H_2O, and then HCN are produced via endothermic gas-phase reactions with H_2. We also calculate molecular line emission and velocity profile, and discuss which lines are affected by disk winds.

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Turbulence in proto-planetary disks: CS as an analytical tracer

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Turbulence is thought to be a key driver of the evolution of proto-planetary disks, regulating the mass accretion process, the transport of angular momentum, and the growth of dust particles. Turbulent motions can be constrained by measuring the non-thermal broadening of line emission from heavy molecules. We use the IRAM Plateau de Bure interferometer to study CS emission in the disk of DM Tau. High spatial ($1.4 \times 1''$) and spectral resolution (0.079 $\mathrm{km\,s^{-1}}$) CS(3-2) images provide constraints on the molecule distribution and velocity structure of the disk. A low sensitivity CS(5-4) image is used in conjunction to constrain the excitation conditions. We analyze the data in terms of two parametric disk models, and compare with detailed time-dependent chemical simulations. The measured intrinsic linewidth derived from the CS(3-2) data is much larger than expected from pure thermal broadening. The magnitude of the derived non thermal component depends very weakly on assumptions about the location of the CS molecules with respect to the disk plane. Our results suggest turbulence with a Mach number around 0.5 in the molecular layer. Geometrical constraints indicate this layer is located between 0.5 - 1.5 scale heights, somewhat lower than predicted by chemical models.

P83

The mass loss history of WX Psc

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Mass loss variations in AGB stars are not uniform nor constant in time, on scales of years to tens of thousands of years. The occurrence of such phenomena is not understood clearly. This work focuses on the well known AGB star WX Psc, for which studies (Decin et al. 2007, Kemper et al. 2003) have shown variations in its wind. Using single dish observations of CO rotational transitions plus SED modeling, mass loss variations between 10^{-5} to 10^{-8} $M_{\odot}$ year^{-1} in the last $\sim$ 2000 years have been inferred. However, such study lacks of spatial resolution of the circumstellar envelope, which can confirm the presence of a mass loss modulation in the form of multiple shells. Using PdBI plus SMA high angular resolution observations, targeting CO (1-0), (2-1) and (3-2), and ^{13}CO (2-1) transitions, we study the spatial and velocity structure at different scales. We also make use of APEX maps in CO (2-1) and (3-2) on even larger scales. We employ our radiative transfer code (Zhao-Geisler et al. in prep, Kemper et al. 2003) to analyse the observations using different mass loss episodes. Our aim is to provide a better understanding of the mass loss history of WX Psc in the spatial and time dimension.

Decin, L. et al. 2007, A&A, 475, 242
Kemper, F. et al. 2003, A&A, 407, 609
Zhao-Geisler, R. et al. in prep.

P84

Spatially Resolving an Extremely Young Intermediate-mass Protostar in Orion

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We present results on the youngest intermediate-mass core located in the Orion Molecular Cloud-3 region, MMS 6-main ($L_{\rm bos} < 60\,{\rm L}_{\odot}$; $M_{\rm core} = 30\,{\rm M}_{\odot}$). No large scale molecular outflow, free-free jet, or infrared source has been detected toward MMS 6-main, suggesting that the core is starless. However, this source is the brightest at submillimeter wavelengths amongst the submillimeter sources detected in OMC-2/3 region. Our spatially resolved SMA 850 μm image shows a massive envelope (0.29 $M_{\odot}$), presence of hot gas ($\geq$52 K), and extremely high column density (N_{H_2} =2.1$\times$10^{25} cm^{-2}) in the central 120 AU. Detailed model comparisons clearly show that a self-luminous source is necessary to explain the observed high flux density, implying that MMS 6-main is not starless. CO and HCN observations further revealed an extremely compact molecular outflow ($\approx$1000 AU) associated with MMS 6-main. The detected outflow has a large-velocity dispersion at the apexes ($\Delta v \sim$25 km s^{-1}), and clearly show bow-shock type velocity structures. The estimated outflow mass ($\approx$10^{-4} $M_{\odot}$) and dynamical time scale ($\approx$200 yr) are one to three orders of magnitude smaller than those estimated in other OMC-2/3 outflows associated with IM Class 0/I sources, while the estimated outflow force ($\approx$10^{-4} $M_{\odot}$ km s^{-1} yr^{-1}) is similarly energetic compared to other outflows, suggesting that MMS 6-main already has molecular outflow launched from a central 2nd core. Moreover, we have spatially resolved at least five sub-clumps within the massive envelope of MMS 6-main. The Masses of the detected sub-clumps are brown dwarf masses and their separation is consistent with the Jeans length, suggesting thermal fragmentation within the massive envelope/disk (Takahashi & Ho 2012, ApJL 745, 10; Takahashi et al. 2012; ApJ, 752, 10).

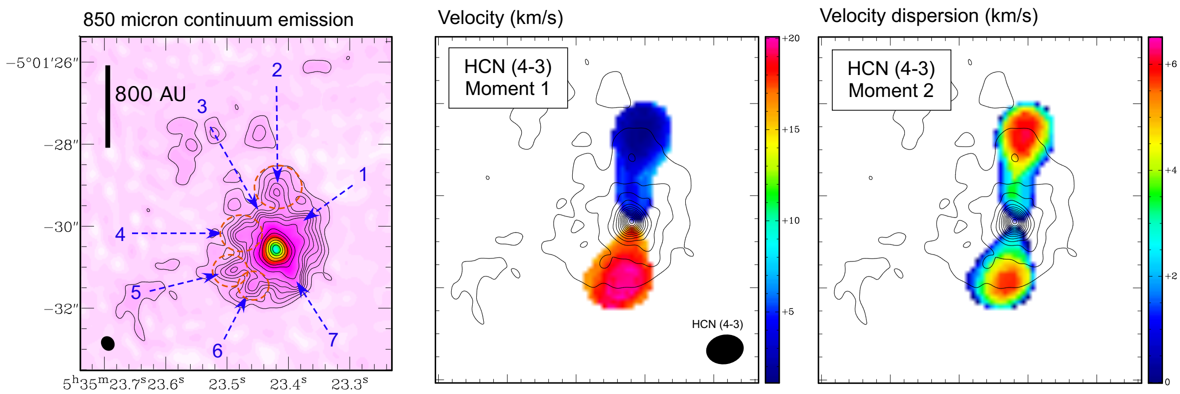

Figure 1: **Left:** 850 μm continuum image obtained with the SMA all configuration data. Dashed circles with numbers show the positions of spiky structures and possible clumps. **Center & Right:** Velocity structure and velocity dispersion of the molecular outflow associated MMS-6 main obtained with HCN (4–3) observations. Background contours show the SMA 850 μ continuum image.

P85

A 1-mm spectral line survey toward GLIMPSE Extended Green Objects (EGOs)

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A northern subsample of 89 *Spitzer GLIMPSE* extended green objects (EGOs), the candidate massive young stellar objects, are surveyed for molecular lines in two 1-GHz ranges: 251.5-252.5 and 260.188-261.188 GHz. A comprehensive catalog of observed molecular line data and spectral plots are presented. Eight molecular species are undoubtedly detected: $H^{13}CO^+$, SiO, SO, CH_3OH, CH_3OCH_3, CH_3CH_2CN, $HCOOCH_3$, and $HN^{13}C$. $H^{13}CO^+$ 3-2 line is detected in 70 EGOs among which 37 ones also show SiO 6-5 line, demonstrating their association to dense gas and supporting the outflow interpretation of the extended 4.5 μm excess emission. Our major dense gas and outflow tracers ($H^{13}CO^+$, SiO, SO and CH_3OH) are combined with our previous survey of ^{13}CO, ^{12}CO and $C^{18}O$ 1-0 toward the same sample of EGOs for a multi-line multi-cloud analysis of line width and luminosity correlations. Good log-linear correlations are found among all considered line luminosities, which requires a universal similarity of density and thermal structures and probably of shock properties among all EGO clouds to explain. It also requires that the shocks should be produced within the natal clouds of the EGOs. Diverse degrees of correlation are found among the line widths. However, both the line width and luminosity correlations tend to progressively worsen across larger cloud subcomponent size-scales, depicting the increase of randomness across cloud subcomponent sizes. Moreover, the line width correlations among the three isotopic CO 1-0 lines show data scatter as linear functions of the line width itself, indicating that the velocity randomness also increases with whole-cloud sizes and has some regularity behind (He, Takahashi, and Chen 2012, ApJS in press.).