Abstract Book

NAOJ Symposium

New Trends in Radio Astronomy in the ALMA Era

The 30th Anniversary of Nobeyama Radio Observatory

30th Anniversary

Hakone, Japan   December 3–8, 2012

Scientific Organizing Committee

Cernicharo, J., Combes, F., Dutrey, A., Hayashi, M., Ho, P. T. P., Inutsuka, S., Kawabe, R., Komatsu, E., Lo, F. K. Y., Scoville, N., van Dishoeck, E. F., Yamamoto, S. (Chair)

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Science Program

December 3 (Mon)

(Opening Session)

9:00 - 9:05 **Opening Remarks** (**Nario Kuno, Director of NRO**)

9:05 - 9:20 **Welcome Address** (**Masa Hayashi, Director General, NAOJ**)

(Cosmology)

(Chairperson: Eiichiro Komatsu)

9:20 – 10:05 **Nick Scoville** (K) *'Evolution of Galaxies and Large Scale Structure at High Redshift'*

10:05 – 10:30 **Tzu-Ching Chang** (I) *'21cm Cosmology: a Progress Report'*

10:30 – 10:50 **Coffee Break**

10:50 – 11:15 **Scott Ransom** (I) *'Detecting Gravitational Waves (and doing other cool physics) with Millisecond Pulsars'*

11:15 – 11:30 **Andrew Blain** (C) *'ALMA before Re-ionization'*

(Galaxies I)

11:30 – 12:15 **Fabian Walter** (K) *'The ISM in Nearby Galaxies'*

12:15 – 13:45 **Lunch Break**

(Chairperson: Daisuke Iono)

13:45 – 14:10 **Kotaro Kono** (I) *'Observations of high redshift galaxies: from Nobeyama to ALMA'*

14:10 – 14:35 **Dominik Riecheres** (I) *'Detailed Studies of Quasars and their Host Galaxies back to the First Billion Years of Cosmic Time'*

14:35 – 15:00 **Francoise Combes** (I) *'High-z Galaxies with ALMA'*

15:00 – 15:15 **Tohru Nagao** (C) *'FIR-submm Metallicity Diagnostics for High-z Galaxies'*

15:15 – 15:30 **Axel Weiss** (C) *'A Redshift Survey of Strongly Lensed Submm Galaxies Based on Molecular Emission Lines Observed with ALMA'*

15:30 – 15:45 **Tadayuki Kodama** (C) *'From Mahalo-Subaru to Gracias-ALMA: Resolving Galaxy Formation at Its Peak Epoch'*

15:45 – 18:00 **Poster Session**

December 4 (Tue)

(Galaxies II)

(Chairperson: Satoki Matsushita)

9:00 - 9:25 **Nario Kuno** (I) *'Giant Molecular Clouds in M33 and M83'*

9:25 - 9:50 **Susanne Aalto** (I) *'Molecules and Chemistry as Tracers of Galaxy Evolution'*

9:50 – 10:15 **Jin Koda** (I) *'Giant Molecular Clouds and Star Formation in Nearby Galaxies'*

10:15 – 10:30 **David Sanders** (C) *'SMA High-Resolution Observations of Molecular Gas in Luminous Infrared Galaxies'*

10:30 – 10:45 **Coffee Break**

(Chairperson: Paul Ho)

10:45 – 11:00 **Junko Ueda** (C) *'Reformation of Cold Molecular Disks in Merger Remnants'*

11:00 – 11:15 **Catherin Vlahakis** (C) *'Molecular gas properties of M100 and ALMA Science Verification'*

11:15 – 11:30 **Daniel Espada** (C) *'Disentangling the circumnuclear environs of Centaurus A: Gaseous Spiral Arms in a Giant Elliptical Galaxy'*

11:30 – 11:45 **Akiko Kawamura** (C) *'Physical Properties of Molecular Clouds in the Magellanic Clouds Revealed by Observations in Multi-Transition CO Molecular Lines'*

11:45 – 12:00 **Kunihiko Tanaka** (C) *'The ASTE Galactic Center Survey in the 350 and 500 GHz Bands'*

12:00 – 12:15 **Mareki Honma** (C) *'Maser Astrometry with VERA and the Galaxy's structure'*

12:15 – 13:45 **Lunch Break**

(Star Formation)

(Chairperson: Sheng-Yuan Liu)

13:45 – 14:30 **Toshikazu Onishi** (K) *'Star Formation: From Giant Molecular Clouds to Prestellar Cores'*

14:30 – 14:55 **Phil Andre** (I) *'Star Formation Revealed by Herschel'*

14:55 – 15:20 **Shantanu Basu** (I) *'Magnetic Fields and Star Formation: The Formation of Cores and Disks'*

15:20 – 15:35 **Satoko Takahashi** (C) *'Hierarchical Fragmentation of the Orion Molecular Filaments'*

15:35 – 15:50 **Tachihara Kengo** (C) *'The Origin of the Intersteller Turbulence and Small Scale Structures of Molecular Clouds'*

15:50 – 16:20 **Coffee Break**

(Chairperson: Fumitaka Nakamura)

16:20 – 16:45 **Patrick Hennebelle** (I) *'Star Formation in Molecular Clouds (Theory)'*

16:45 – 17:00 **Jonathan Tan** (C) *'The Dynamics and Chemistry of Massive Starless Cores'*

17:00 - 17:15 **Jonathan Foster** (C) *'The Millimeter Astronomy Legacy Team 90 GHz Survey (MALT90) and ALMA'*

17:15 – 17:30 **John Tobin** (C) *'A Resolved Keplerian Disk Around One of the Youngest Protostars: Implications for Disk Formation Studies in the ALMA Era'*

17:30 – 17:45 **Shigehisa Takakuwa** (C) *'Keplerian Circumbinary Disk and Accretion Streams around the Protostellar Binary System L1551 NE'*

17:45 – 18:00 **Nagayoshi Ohashi** (C) *'Keplerian Disks around Protostars: from NMA to SMA and ALMA'*

December 5 (Wed)

(Protoplanetary Disks)

(Chairperson: Nagayoshi Ohashi)

9:00 – 9:45 **Ann Dutrey** (K) *'Structure of Protoplanetary Disks as Inferred from mm/submm Interferometry'*

9:45 – 10:10 **Sean Andrews** (I) *'The Structures of Protoplanetary Disks'*

10:10 – 10:35 **Misato Fukagawa** (I) *'High Angular Resolution Infrared Observations of Protoplanetary Disks'*

10:35 – 11:05 **Coffee Break**

(Chairperson: Shu-ichiro Inutsuka)

11:05 – 11:20 **Motohide Tamura** (C) *'SEEDS: Direct Imaging of Exoplanets and Their Forming Disks with the Subaru Telescope'*

11:20 – 11:35 **Leonardo Testi** (C) *'Observational constraints on disk evolution and the initial steps towards planet formation'*

11:35 – 12:00 **Mark Wyatt** (I) *'Sub-mm Studies of Debris Disks'*

12:00 – 12:15 **Devid Wilner** (C) *'Resolved Millimeter Emission Belts in the β Pictoris and AU Microscopii Debris Disks'*

12:15 – 13:45 **Lunch Break**

(Astrochemistry)

(Chairperson: Peter Schilke)

13:45 – 14:30 **Ewine van Dishoeck** (K) *'New Trends in Astrochemistry in the ALMA Era'*

14:30 – 14:55 **Paola Caselli** (I) *'Pre-stellar Cores and Infrared Dark Clouds'*

14:55 – 15:20 **Mario Tafalla** (I) *'Molecules in Bipolar Outflows from Young Stellar Objects'*

15:20 – 15:45 **Nami Sakai** (I) *'Chemical Diversity of Low-Mass Star-Forming Cores: Class 0 to Class I'*

15:45 – 16:10 **Coffee Break**

(Chairperson: Masatoshi Ohishi)

16:10 – 16:35 **Edwin Bergin** (I) *'Chemistry in Star-Forming Regions: Herschel Looking towards ALMA'*

16:35 – 16:50 **Shuro Takano** (C) *'Nobeyama 45 m telescope legacy project: Line survey'*

16:50 – 17:05 **Bertrand Lefloch** (C) *'Shocks in Low-Mass Protostellar Environments: Present Lessons and Future Observations'*

17:05 – 17:30 **Yuri Aikawa** (I) *'Chemical Models of Star Forming Cores'*

17:30 – 17:45 **Edwige Chapillon** (C) *'Observations of Chemistry in Protoplanetary Surrounding Low-Mass Stars'*

17:45 – 18:00 **Hideko Nomura** (C) *'Diagnosing Gas Dispersal Processes in Protoplanetary Disks'*

December 6 (Thu)

(Solar System)

(Chairperson: Stephane Guilloteau)

9:00 - 9:45 **Mark Gurwell** (K) *'Planetary Atmospheres at High Resolution'*

9:45 – 10:10 **Bryan Butlar** (I) *'Observations of Smaller Solar System Objects at submm-cm Wavelengths'*

(Evolved Stars etc.)

(Chairperson: Claudine Kahane)

10:10 – 10:55 **Jose Cernicharo** (K) *'The Chemistry of Carbon and Oxygen-rich Evolved Stars'*

10:55 – 11:10 **Coffee Break**

11:10 – 11:35 **Leen Decin** (I) *'Herschel's view on late stages of stellar evolution - New enigmas to be solved with ALMA -'*

11:35 – 12:00 **Naomi Hirano** (I) *'Outflows in Late-type Stars'*

12:00 – 12:35 **Leonardo Bronfman** (I) *'From Large Scale Surveys to ALMA Observations of Massive Star Forming Regions'*

12:35 – 14:00 **Lunch Break**

14:00 – 16:00 **Poster Session**

18:30 - **Banquet**

After Dinner Talk (Norio Kaifu)

December 7 (Fri)

9:00 – 9:15 **Session for Professor Morita**

(Future Plans I)

(Chairperson: Munetake Momose)

9:15 – 9:40 **Thijs de Graauw** *'ALMA: The Challenge of Construction and Operation')*

9:40 – 10:05 **Daisuke Iono** (C) *'Future Dvelopment of ALMA'*

10:05 – 10:30 **Pierre Cox** (I) *(IRAM: Present and Future)*

10:30 – 10:50 **Coffee Break**

10:50 – 11:15 **Ryohei Kawabe** (I) *'The Large Millimeter and Sub-millimeter Telescope Project, "ALMA SPICA Synergy Telescope (ASTe)"'*

11:15 – 11:40 **Gordon Stacy** (I) *'The CCAT Project'*

11:40 – 12:05 **Min Yun** (I) *'The LMT in the ALMA Era'*

12:05 – 12:20 **Fumitaka Nakamura** (C) *'The CCS 45 GHz Zeeman Project: Magnetic Field Measurements Towards Prestellar Cores'*

12:20 – 14:00 **Lunch Break**

(Future Plans II)

(Chairperson: Mareki Honma)

14:00 – 14:25 **Takao Nakagawa** (I) *'The Next Generation Infrared Astronomy Mission SPICA'*

14:25 – 14:50 **Sheperd Doleman** (I) *'The Event Horizon Telescope: Observing Black Holes with Schwarzschild Radius Resolution'*

14:50 – 15:05 **Keiichi Asada** (C) *'The Greenland Telescope (GLT) Project'*

(Closing Session)

15:05 – 16:00 **Concluding Remarks**

A LIST OF POSTER PRESENTATIONS

A poster board will fit the A0 size poster (W: 84.1 cm H: 118.9 cm). Poster sessions are held on Monday (Dec. 3) and Thursday (Dec. 6). Good posters will be awarded.

Evolution of Galaxies and Large Scale Structure at High Redshift

N. SCOVILLE[1]

[1] Caltech, Pasadena, CA.

I present extensive mapping and analysis of large scale structure in the COSMOS survey field with a detailed comparison with the Millennium simulation. The properties of the galaxies – mass, SFR and SED are found to be strongly correlated with the large scale structure environment. Initial results from our ALMA cycle0 projects will also be presented. One project measures the dust continuum in a sample of 60 galaxies to enable estimates of the ISM contents and the evolution of the ISM mass with redshift. The 2nd project provides Band 7 & 9 observation of HCN and H26 Alpha at 0.25 - 0.5 arcsec resolution for Arp 220 and NGC 6240. These low redshift ULIRG galaxies are probably excewllent analogs for understanding evolution in the early universe.

21 cm Cosmology: a Progress Report

TZU-CHING CHANG[1]

[1] ASIAA

Hydrogen is the most abundant baryonic element in the universe, and in its neutral phase (HI) radiates at a wavelength of 21-cm. The redshifted 21-cm line can potentially probe a significant fraction of the universe, shedding light on astrophysical processes and fundamental physics. Recently, two observational redshift windows have emerged in the "intensity mapping" regime: around the epoch of cosmic reionization (EoR), 21-cm line directly traces the distribution and evolution of neutral/ionized regions, probing the reionization history; at redshifts around unity, 21-cm follows large-scale structure and can be used to measure the Baryon Acoustic Oscillation signature, constraining the properties of dark energy. I will describe our current efforts in these two fields, utilizing the Giant Metrewave Radio Telescope (the GMRT-EoR project) and the Green Bank Telescope (GBT), aiming to measure the 21-cm power spectrum at redshifts around nine and one, respectively. Initial results are encouraging.

Detecting Gravitational Waves (and doing other cool physics) with Millisecond Pulsars

SCOTT RANSOM[1]

[1] National Radio Astronomy Observatory

The first millisecond pulsar was discovered in 1982. Since that time their use as highly-accurate celestial clocks has improved continually, so that they are now regularly used to measure a variety of general relativistic effects and probe a variety of topics in basic physics, such as the equation of state of matter at supra-nuclear densities. One of their most exciting uses though, is the current North American (NANOGrav) and international (the International Pulsar Timing Array) efforts to directly detect nanohertz frequency gravitational waves, most likely originating from the ensemble of supermassive black hole binaries scattered throughout the universe. In this talk I'll describe how we are using an ensemble of pulsars to try to make such a measurement, how we could make a detection within the next 5-10 years, and how we get a wide variety of very interesting secondary science from the pulsars in the meantime.

ALMA before re-ionization.

A. BLAIN[1]

[1] University of Leicester, UK.

ALMA is a genuinely transformational facility. Its precision and sensitivity enable quite new things to be done. I will describe the way in which ALMA can be used to investigate the first light and the collapse of the first objects, by combining its great power with the additional tools of gravitational lensing to probe to distances at which lower-resolution instruments are blinded by confusion, and facilities operating at shorter wavelengths are unable to reach. The collapse and processing of metal-free gas, the debris of the first stars, and the fueling of the first blackholes are all accessible to ambitious but practical ALMA observations, using a range of signatures from molecular hydrogen, the Sunyaev–Zel'dovich effect, and conventional molecular tracers. There are several synergies with *JWST*, ELTs and SKA.

The ISM in Nearby Galaxies

FABIAN WALTER [1]

[1] Max-Planck-Institut für Astronomie

Remarkable progress has been achieved in recent years in quantifying the molecular, atomic and dusty properties of the interstellar medium (ISM) and their relation to star formation in nearby galaxies. This is mainly thanks to a number of dedicated multi-wavelength surveys (infrared [Spitzer, Herschel], optical, UV [Galex], CO [e.g., IRAM], HI [VLA]) that targeted a sample of nearby galaxies. I will highlight some of the recent results emererging from these efforts and review our current understanding of the ISM properties, with a focus on the molecular gas phase, and its relation to star formation in nearby galaxies. I will close by presenting some new high-J CO observations of nearby galaxies from Herschel and some of the early results that ALMA provided in cycle 0 observations.

Observations of high redshift galaxies: from Nobeyama to ALMA

K. Kohno[1]

[1] The University of Tokyo

Observing facilities operated by Nobeyama Radio Observatory (NRO), including Nobeyama 45 m telescope, Nobeyama Millimeter Array (NMA), and Atacama Submillimeter Telescope Experiment (ASTE)[1], have been played important roles on the study of interstellar medium in high redshift galaxies (e.g., Kawabe et al. 1992; Ohta et al. 1996; Tamura et al. 2009).

In this talk, we will focus on 3 recent follow up studies of confusion-limited deep 1.1 mm surveys conducted with AzTEC camera (Wilson et al. 2008) mounted on ASTE 10 m dish (Ezawa et al. 2008). Emphasis will be also placed on the roles of ALMA on these studies.

1. Dust-obscured star formation in Lyα brobs and emitters in the proto-cluster SSA 22 around $z \sim 3.1$ (Tamura et al. 2012). Relation among submillimeter galaxies, large scale structures (Tamura et al. 2009; Hatsukade et al. 2012), and quasar formation within them (Tamura et al. 2010), will also be discussed.

2. Dust-obscured star formation in the mm/submm bright Hα emitters in the proto-cluster at $z \sim 2.5$ around the radio galaxy 4C23.56 (Suzuki et al. 2012). PdBI imaging studies of bright submillimeter galaxies in this region will also be presented.

3. Ultra-bright mm-selected galaxies and their follow up observations (Ikarashi et al. 2011; Takekoshi et al. 2012). TZ100/SAM45, a newly developed 3-mm band redshift machine for NRO 45 m telescope (Nakajima et al. 2012) will be introduced, along with the early science verification results (Iono et al. 2012).

References:

Ezawa, H. et al., 2008, "New achievements of ASTE: the Atacama Submillimeter Telescope Experiment", in Stepp L. M., Gilmozzi R., eds, Proc. SPIE Vol. 7012, Ground-based and Airborne Telescopes II. SPIE, Bellingham, p.701208 • Hatsukade, B., et al. 2012, "Clustering Properties of 1.1 mm-selected Submillimetre Galaxies Uncovered by AzTEC Deep Surveys", to be submitted to MNRAS • Ikarashi, S., et al. 2011, "Detection of an ultrabright submillimetre galaxy in the Subaru/XMM-Newton Deep Field using AzTEC/ASTE", MNRAS, 415, 3081 • Iono, D., et al. 2012, "Initial Results from Nobeyama Molecular Gas Observations of Distant Bright Galaxies", PASJ, 64, L2 • Kawabe, R., et al. 1992, "Aperture synthesis CO (J = 3-2) observations of a protogalaxy candidate IRAS F10214+4724", ApJ, 397, 23 • Nakajima, T., et al. 2012, "A New 100-GHz Band Two-Beam Sideband-Separating SIS Receiver for Z-Machine on the NRO 45-m Radio Telescope", PASJ, submitted • Ohta, K., et al. 1996, "Detection of molecular gas in the quasar BR1202-0725 at redshift z = 4.69", Nature, 382, 426 • Suzuki, K., et al. 2012, "AzTEC on ASTE Observations of the Proto-cluster at $z \sim 2.5$: Spatial Association of 1.1 mm Sources with Hα Emitters around 4C 23.56", to be submitted to MNRAS • Takekoshi, T., et al. 2012, "Detection of an Ultra-bright Submillimeter Galaxy behind the Small Magellanic Cloud", to be submitted to ApJ • Tamura, Y., et al., 2009, "Spatial correlation between submillimetre and Lyman-α galaxies in the SSA22 protocluster", Nature, 459, 61 • Tamura, Y., et al. 2010, "Submillimeter Array Identification of the Millimeter-selected Galaxy SSA22-AzTEC1: A Protoquasar in a Protocluster?", ApJ, 724, 1270 • Tamura, Y., et al., 2012, "Obscured star formation in Lyα brobs at $z = 3.1$", MNRAS, submitted • Wilson, G. W., et al., 2008, "The AzTEC mm-wavelength camera", MNRAS, 386, 807

[1]ASTE is now operated by Chile Observatory, NAOJ, from FY2012

Detailed Studies of Quasars and their Host Galaxies back to the First Billion Years of Cosmic Time

DOMINIK A. RIECHERS[1]

[1] Cornell University, USA.

Detailed studies of the molecular gas phase in the host galaxies of the highest redshift quasars are important for our understanding of the formation and evolution of quasars and their bulges, since it is the molecular gas out of which stars form. I will highlight a number of key results from our recent studies with the IRAM Interferometer (PdBI), the recently upgraded Jansky Very Large Array (JVLA), and the Atacama Large Millimeter/submillimeter Array (ALMA), which is nearing completion in the coming months. These investigations have substantially improved our understanding of the mass, excitation, composition, morphology, dynamical structure, and environments of the molecular and cold neutral interstellar medium in quasar host galaxies out to $z>6$. Our observations and analysis uniquely constrain the properties of the molecular environments in some of the most active and most massive among the most distant galaxies currently observable, and thus, provide an important foundation for future studies with CCAT and full ALMA.

High-z Galaxies with ALMA

F. Combes[1]

[1] Paris Observatory, France.

ALMA opens a new window on primordial galaxies, and on galaxy formation, up to the reionisation epoch. The detection of dust emission at z=5-10 is as easy than at z=1 due to the negative K-correction, and the high gas excitation in denser star forming regions allows easy detection of high-J CO lines. At least 100 times more sources than with present instruments could be discovered, so that more normal galaxies, with lower luminosities than huge starbursts and quasars will be surveyed. The high spatial resolution will suppress the confusion, which affects single dish bolometer surveys.

The broad-band receivers will allow to determine with CO lines the redshift of objects too obscured to be seen in the optical. With the present instrumentation, only the most masssive and gas rich objects have been detected in CO at high z, most of them being ultra-luminous starbursts with an extremely high star formation efficiency, or highly amplified by gravitational lenses. However, selection biases are omnipresent in this domain, and ALMA will statistically clarify the evolution of star formation efficiency, being fully complementary to JWST and ELTs.

FIR-submm Metallicity Diagnostics for High-z Galaxies

T. NAGAO[1,2], R. MAIOLINO[3], C. DE BREUCK[4], P. CASELLI[5], B. HATSUKADE[2], A. MARCONI[6], H. MATSUHARA[7], K. SAIGO[8]

[1] The Hakubi Center for Advanced Research, Kyoto Univ., Japan.
[2] Department of Astronomy, Graduate School of Science, Kyoto Univ., Japan.
[3] Cavendish Laboratory, Univerisy of Cambridge, UK.
[4] European Southern Observatory, Germany.
[5] School of Physics and Astronomy, University of Leeds, UK.
[6] Department of Physics and Astronomy, University of Florence, Italy.
[7] Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, Japan.
[8] East Asian ALMA Regional Center, National Astronomical Observatory of Japan, Japan.

The chemical properties of galaxies provide important information to constrain galaxy evolutionary scenarios. However, widely-used metallicity diagnostics based on rest-frame optical emission lines are not usable for heavily dust-enshrouded galaxies such as sub-millimeter galaxies (SMGs) and ultraluminous infrared galaxies (ULIRGs) due to serious dust reddening effects. The rest-frame optical emission lines are particularly useless at $z > 3.5$, where those emission lines shift out from the near-infrared atmospheric windows.

Here we report new diagnostics of the gas metallicity based on infrared fine-structure emission lines, which are nearly unaffected by dust extinction even the most obscured systems (Nagao et al. 2011). We then apply our approach to a strongly [CII]-emitting SMG, LESS J033229.4-275619 at z=4.76, whose [NII]205 emission is detected through our ALMA cycle 0 observation. The observed [NII]/[CII] flux ratio and photoionization models suggest that the metallicity in this SMG is consistent with the solar metallicity, implying the chemical evolution has progressed very rapidly in this system even at such high-z (Nagao et al. 2012).

A redshift survey of strongly lensed submm galaxies based on molecular emission lines observed with ALMA

A. Weiss[1], C. de Breuck[2], J. Vieira[3], D. Marrone[4], Y. Hezaveh,[5] S. Chapman[6], & the SPT-SMG team

[1] MPIfR, Germany,
[2] ESO, Germany,
[3] Caltech, USA,
[4] Steward Observatory, USA
[5] McGill Uni., USA
[6] Cambridge, UK

Recent ground and space-based multi wavelength (sub)millimeter surveys covering hundreds of square degrees have discovered a large number of strongly lensed, ultra-bright submm galaxies (SMGs). The largest of these, by nearly an order of magnitude at present, is the South Pole Telescope (SPT) survey, which covers 2500 deg^2. Its 1.4 mm detection wavelength ensures a uniform source selection function across $z = 1 - 8$ and makes this survey a perfect repository to study the high redshift tail of the SMGs population. In my talk I will present the results of a blind redshift survey in the 3 mm transmission window in a sample of SPT sources using ALMA. This survey is a large success with 45 detected line features which we identify as redshifted emission lines of ^{12}CO, ^{13}CO, C I, H_2O and H_2O^+. At least 60% of our sample is found to be at $z > 3$ with two sources at $z = 5.7$ placing them among the most distant SMGs known today. Our study suggests that previous SMG redshift survey, which are almost exclusively based on radio identified sources, may have missed a large fraction ($\geq$ 60%) of the SMG population as it resides at redshifts $z > 3$. An alternative interpretation, however, is that the SMG population undergoes a size evolution with decreasing submm emission regions for increasing redshifts. In this case the observed higher redshifts could be a bias due to gravitational lensing.

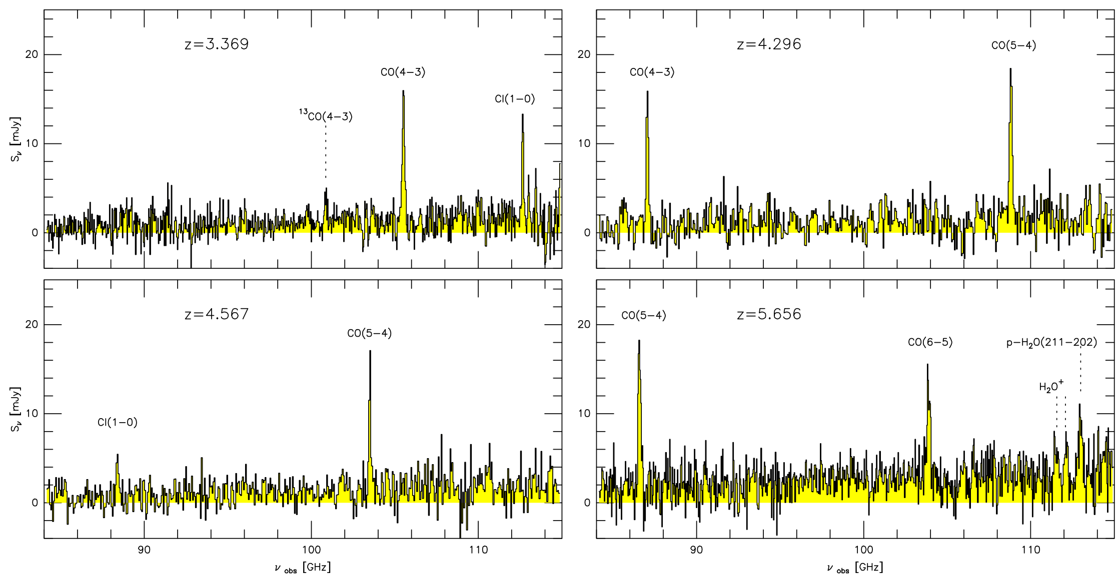


Figure 1: Examples of the ALMA 3 mm spectra obtain by us in cycle 0. The spectra demonstrates the richness of our survey with detections of ^{12}CO, ^{13}CO, C I, H_2O and H_2O^+.

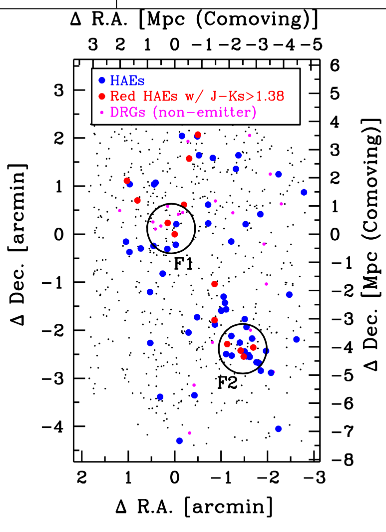
From Mahalo-Subaru to Gracias-ALMA: Resolving Galaxy Formation at Its Peak Epoch

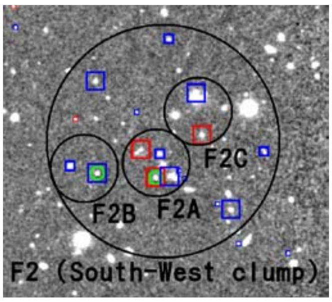
T. KODAMA[1], M. HAYASHI[2], Y. KOYAMA[2], K. TADAKI[2], AND GRACIAS-ALMA TEAM
[1] Subaru Telescope [2] Optical-NIR division, NAOJ

The redshift interval of 1.5–2.5 is the critical era for galaxy evolution when the star forming and AGN activities are both highest. Also, galaxy formation and subsequent evolution should be dependent on environment given the clear habitat segregation of different types of galaxies seen today. It is essential therefore to systematically search for star forming galaxies over this critical epoch and across different environments, and investigate their physical properties in detail. For this purpose, we design a fully coordinated program between Subaru and ALMA. The Mahalo-Subaru project has been mapping out star-forming galaxies (eg. Hα emitters) at $1.5 \leq z \leq 2.5$ across various environments by employing the unique set of custom-made narrow-band filters and wide-field cameras. We have discovered large scale structures in and around proto-clusters, complex clumpy structures of individual galaxies, and clear environmental dependence of galaxy properties such as stellar mass and star formation rate. We now propose the Gracias-ALMA project which aims to observe CO lines and dust continua of the star-forming galaxies sampled by Mahalo-Subaru, with great spatial resolution and high sensitivity. We will resolve and scrutinize the physical states and the mode of star formation within galaxies, and identify the physical processes that governs star-forming activities as a function of time and environment. In this talk, we will present the highlights of the Mahalo-Subaru project and describe the prospects for the Gracias-ALMA project.

(Table) The list of Gracias-ALMA core targets. 6 proto-clusters and a general field (SXDF-UDS-CANDELS) are selected from the sample of Mahalo-Subaru narrow-band emitter survey.

		Mahalo-Subaru				Gracias-ALMA	
target	z	line	μm	NB-filter	Camera	Continuum	Line@GHz(band)
2215–1738	1.46	[OII]	0.916	NB912	S-Cam	B7,9	CO(2-1)@94 (B3)
0332–2742	1.61	[OII]	0.973	NB973	S-Cam	B7,9	CO(2-1)@89 (B3)
0218.3–0510	1.62	[OII]	0.977	NB973	S-Cam	B7,9	CO(2-1)@88 (B3)
1138–262	2.16	Hα	2.071	NB2071	MOIRCS	B6,7,9	CO(3-2)@110 (B3)
4C23.56	2.48	Hα	2.286	NB2288	MOIRCS	B6,7,9	CO(3-2)@99 (B3)
1558–003	2.53	Hα	2.315	NB2315	MOIRCS	B6,7,9	CO(3-2)@98 (B3)
SXDF-UDS	2.19	Hα	2.094	NB2095	MOIRCS	B6,7,9	CO(3-2)@108 (B3)
-CANDELS	2.53	Hα	2.315	NB2315	MOIRCS	B7,6,9	CO(3-2)@98 (B3)





(left) A 2-D map of the USS1558 proto-cluster at z=2.53, based on Mahalo-Subaru. Red and blue circles indicate red and blue Hα emitters, respectively, and purple filled circles show DRGs (distant red galaxies) without detectable emiss ion. This result is published in Hayashi et al. (2012, ApJ, in press). **(right)** A close-up view of F2. Large circles show the field of view of Band-3 (62″), and the small circles show that of Band-7 (18″). Red and blue squares indicate the red and blue Hα emitters, respectively. Note its extremely high density of strong emitters. Sizes of the squares correspond to 3 classes in star formation rates, separated at 60 and 100 $M_\odot$/yr.

Giant Molecular Clouds in M33 and M83

N. KUNO[1]

[1] Nobeyama Radio Observatory, NAOJ

I will review the results of the NRO legacy project "M33 All Disk Survey of Giant Molecular Clouds (NRO-MAGiC)". We mapped the whole disk of M33 in CO(1-0) with NRO 45-m telescope and a large fraction of the disk in CO(3-2) with ASTE 10-m telescope. Furthermore, we obtained 1.1 mm continuum map of M33 with ASTE. Main results of the project are summarized as the followings.

(1) Transition from atomic gas to molecular gas (Tosaki et al. 2011)

We found that the efficiency of molecular gas formation is higher in the inner region ($R < 2$kpc) than the outer region. Since there is a sharp increase of metallicity in M33, the main cause may be the radial variation of metallicity.

(2) Evolution of Giant Molecular Clouds (Onodera et al. 2012, Miura et al. 2012)

We investigated the relation between CO(3-2)/CO(1-0) ratio and star formation activity. We also investigated the relation between the ratio and GMC mass. As a result, we found that the GMCs with high activity of star formation tend to have higher CO(3-2)/CO(1-0) ratio. Furthermore, the ratio of more massive GMCs tend to be higher. These results imply that the fraction of dense and warm molecular gas increases with star forming activity along with the evolution of GMCs. The results also imply that the fraction of dense gas increases with GMC mass. On the other hand, the GMCs are classified into 4 classes based on the star forming activity. Differences of some properties of the GMCs in those classes are seen.

(3) Relation between molecular gas and star formation (Onodera et al. 2010)

We tested to what scale the Kennicutt-Schmidt law is valid by changing spatial resolution from 1 kpc to 80 pc. We found that the correlation becomes looser with higher resolution and that the K-S law becomes invalid in GMC scale ($\sim$ 80 pc). In this scale we can see the variation of evolutionary stage of the GMCs. It may be the cause of the breakdown of the K-S law in GMC scale.

(4) Temperature variation of cold dust (Komugi et al. 2011)

Using our 1.1 mm data and the Spitzer data, we found a smooth temperature gradient in the Disk of M33. The temperature decreases from the inner to outer region.

Based on the observations of GMCs in nearby galaxies such as M33, IC342 (Hirota et al. 2011) and M83 (Muraoka et al. 2009), we planed a survey of GMCs in M83 with ALMA and the proposal for Cycle 0 was accepted (PI. Hirota). If the data of ALMA cycle 0 is delivered before the conference, I will present the results also.

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Miura, R. et al. 2012, ApJ submitted
Muraoka, K. et al. 2009, ApJ, 706, 1213
Muraoka, K. et al. 2012, PASJ, 64, 3
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Tosaki, T. et al. 2011, PASJ, 63, 117

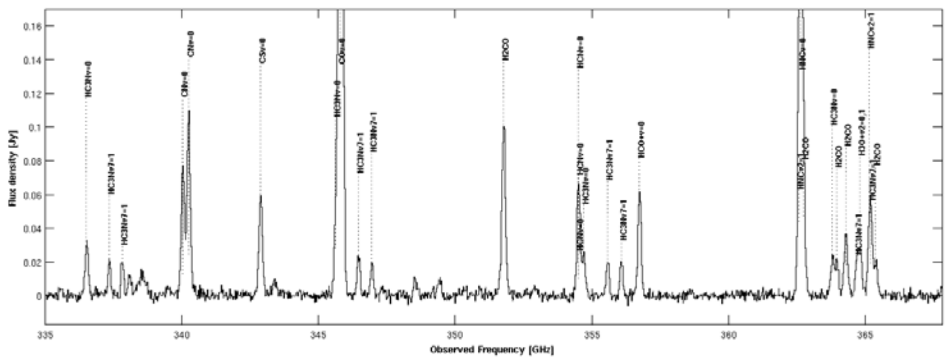
Molecules and Chemistry as Tracers of Galaxy Evolution

S. Aalto[1]

[1] Department of Earth and Space Sciences, Chalmers university of Technology, Sweden.

Intense bursts of star formation and feeding of SMBHs occur when collisions of gas-rich galaxies funnel massive amounts of molecular gas and dust into nuclei of luminous and ultraluminous infrared galaxies (LIRGs/ULIRGs). Much of the ongoing research into initial phases of galaxy building also focuses on the pre-ULIRG phases of super-starbursts, QSOs and assembly of galaxies via major mergers. These phases parallel conditions in lower luminosity starbursts and thus studies of nearby and rapidly evolving LIRGS, ULIRGS, and AGN, are essential both for defining the evolution of present day galaxies and sorting out key astrophysical processes in their more distant predecessors.

I will present methods of studying galaxy evolution through using molecules as observational tools exploiting their ability to trace dynamical, chemical and physical conditions. I will discuss new techniques where the most compact obscured nuclei (CONs), for example, can be studied with radiatively excited molecular emission getting past the optically thick barrier. Furthermore, key molecules in identifying the nature of buried activity and its evolution will be discussed. Finally, I will present recent results on molecular outflows in a selection of nearby LIRGs and ULIRGs.



Simulated 0.8mm spectrum for the CON LIRG NGC4418, T=85 K. (From our successful ALMA Cycle 0 proposal to carry out a spectral scan of NGC4418 (PI:F.Costagliola)).

Giant Molecular Clouds and Star Formation in Nearby Galaxies

JIN KODA[1]

[1] Stony Brook University

The Nobeyama 45m telescope and millimeter array, as well as other mm and submm telescopes in the world, contributed significantly to our understanding of molecular gas and its evolution in galaxies. ALMA is revolutionizing the study of giant molecular cloud (GMC) evolution in nearby galaxies, by not only detecting, but resolving the internal properties of individual GMCs in spiral galaxies down to the ”Taurus” cloud mass – compared to mere detection of ”Orion”s by the existing telescopes. I will summarize recent results and future prospects on the evolution of molecular gas and star formation in nearby galaxies, with a particular emphasis on GMCs and star formation.

SMA High-Resolution Observations of Molecular Gas in Luminous Infrared Galaxies

D. B. Sanders[1]

[1] University of Hawaii, Institute for Astronomy.

We report new, high-resolution (0.3-0.5 arcsec) observations with the Smithsonian Sub-millimeter Array (SMA) on Mauna Kea, of 10 luminous and ultra-luminous infrared galaxies, (U)LIRGs, selected from the Great Observatories All-Sky LIRG Survey (GOALS). These data are used to determine the total mass and compactness of the molecular gas distributions, and to search for double nuclei, extended spatial structure (e.g. compact disks, bars, rings) and interesting kinematic features such as high-velocity outflows. We highlight the cases of the clear double nucleus sources, NGC 6240 and Mrk 273 – objects which clearly contain two high luminosity active nuclei (AGN), and discuss the relationship of the AGN activity to the surrounding nuclear starburst.

Reformation of Cold Molecular Disks in Merger Remnants

J. UEDA[1,2,3], D. IONO[2], M. YUN[4], D. WILNER[3], D. NARAYANAN[5], B. HATSUKADE[6], Y. TAMURA[1], H. KANEKO,[7], A. CROCKER[4], D. ESPADA[2], R. KAWABE[2,8],

[1] Univ. of Tokyo, Japan. [2] NAOJ,Japan. [3] Harvard-Smithsonian CfA, US. [4] UMass, US. [5] Univ. of Arizona, US. [6] Kyoto Univ., Japan. [7] Univ. of Tsukuba, Japan. [8] JAO, Chie.

It has been long predicted from numerical simulations that a major merger of two disk galaxies results in a formation of the spheroid-dominated early-type galaxy. Contrary to this classical scenario of galaxy merger evolution, recent simulations with more realistic gas physics have shown that not all of the major mergers will become an early-type galaxy, but some will reemerge as a disk dominated late-type galaxy.

In order to check this scenario and look for observational evidence of a forming molecular disk in merger remnants, we have investigated the CO data of a sample of merger remnants obtained with single-dish telescopes and interferometers, including the NRO 45-m telescope and ALMA (Cycle 0). Our sample is selected based on K-band morphology suggesting advanced stages of the merger. By investigating the interferometric velocity field and fitting with concentric rings, we found that 14 sources (70%) can be modeled by disk rotation. We thus suggest that molecular disk formation is common at the final stages of mergers. In addition, we found that the CO surface brightness profiles of these sources are roughly distributed as exponential disks. The sizes of the molecular disks R_{80} (radius enclosing 80% of the total CO flux) range from 0.5 to 5.0 kpc, and the spatial extent of the largest molecular disk is comparable to the size of the Milky Way disk.

Molecular gas properties of M100 and ALMA Science Verification

C. Vlahakis[1,2], S. Leon[1,2], G. Bendo[3], D. Garcia[1,2], S. Martin[2], M. Zwaan[4]

[1] Joint ALMA Observatory, Chile.
[2] European Southern Observatory, Chile.
[3] UK ALMA Regional Centre Node, UK.
[4] European Southern Observatory, Germany.

I will present an overview of Atacama Large Millimetre/submillimetre Array (ALMA) Science Verification results, and will focus on CO J=1-0 ALMA Science Verification observations of M100, a nearby 'grand-design' barred spiral galaxy in the Virgo cluster. M100 has abundant molecular gas in its centre, long spiral arms dominating its optical disk and has a relatively face-on inclination (i$\sim$30 degrees). Due to its proximity ($\sim$16 Mpc) and relatively face-on inclination, M100 is an ideal target for molecular gas studies, and has been the subject of a number of previous interferometric studies in CO with, for example, the Nobeyama mm-wave Array (Sakamoto et al. 1995, 1999), the IRAM interferometer (Garcia-Burillo et al. 1998), and the Berkeley-Illinois-Maryland Association (BIMA) millimeter interferometer array (Regan et al. 2001, Helfer et al. 2003). We compare the ALMA CO data, at a spatial resolution of $\sim$200 pc, with previously unpublished H I data taken with the Very Large Array (VLA). We describe the integrated intensity maps and compare them to other data from the literature to investigate the variation of the molecular gas, atomic gas and star formation properties. Using the velocity field and velocity dispersion maps we also investigate the gas dynamics.

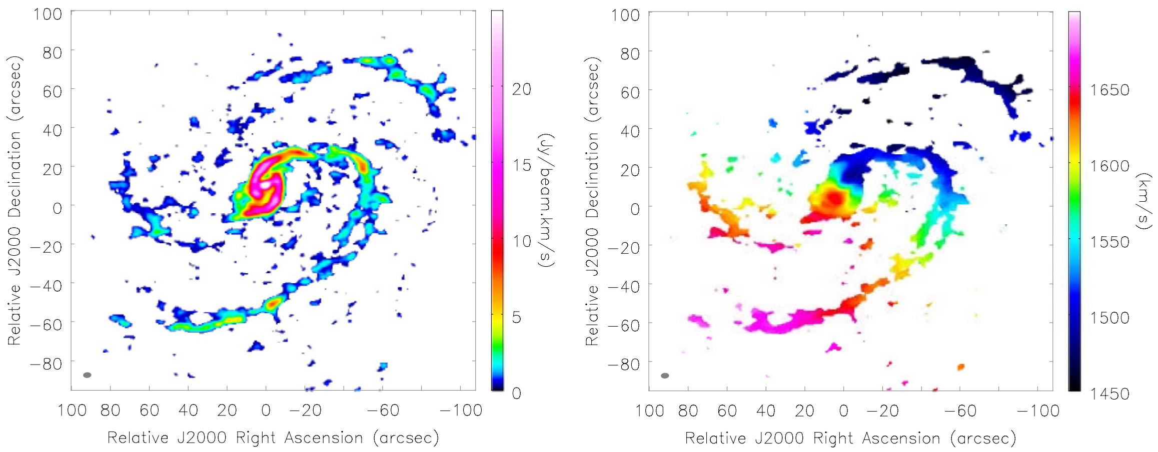


Figure 1: ALMA CO J=1-0 integrated intensity (left) and velocity field (right) images of M100.

References:

Garcia-Burillo S., Sempere, M.J., Combes F., & Neri, R., 1998, A&A, 333, 864
Helfer T. T., et al., 2003, ApJS, 145, 259
Sakamoto K., et al., 1999, ApJS, 124, 403
Sakamoto K., et al., 1995, AJ, 110, 2075

Disentangling the circumnuclear environs of Centaurus A: Gaseous Spiral Arms in a Giant Elliptical Galaxy

D. ESPADA[1]

[1] NAOJ, Japan.

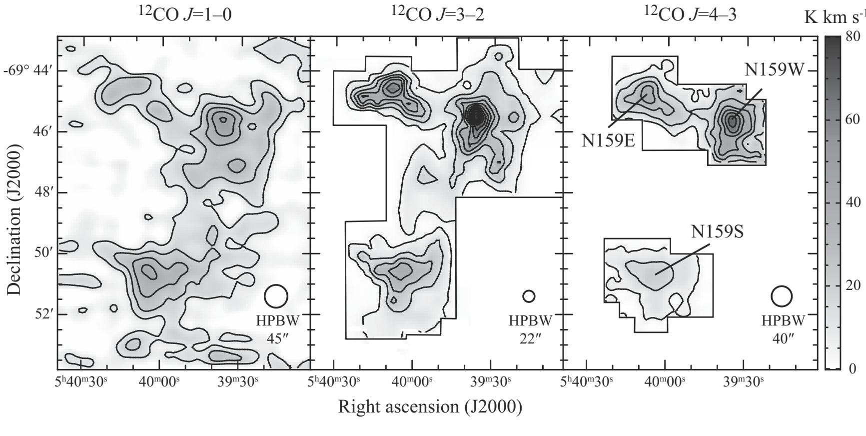
We report the existence of spiral arms in the recently formed gaseous and dusty disk of the closest giant elliptical, NGC 5128 (Centaurus A), using high resolution 12CO(2–1) observations of the central 3 arcmin (3 kpc) obtained with the Submillimeter Array (SMA), and confirmed by ALMA science verification observations. This provides evidence that spiral-like features can develop within ellipticals if enough cold gas exists. The spiral arms extend from the circumnuclear gas at a radius of 200 pc to at least 1 kiloparsec. The general properties of the arms are similar to those in spiral galaxies: they are trailing, the width is $\sim 500 \pm 200$ pc, and the pitch angle is 20 degree. From independent estimates of the time when the HI-rich galaxy merger occurred, we infer that the formation of spiral arms happened on a time scale of less than 10^8 yr. The formation of spiral arms increases the gas density and thus the star formation efficiency in the early stages of the formation of a disk.

Physical properties of molecular clouds in the Magellanic Clouds revealed by observations in multi-transition CO molecular lines

A. KAWAMURA[1], T. ONISHI[2], T. MINAMIDANI[3], N. MIZUNO[1], K. FUJII[1], E. MULLER[1], Y. FUKUI[4]

[1] National Astronomical Observetory, Japan.
[2] Osaka Prefecture University, Japan. [3] Hokkaido University, Japan. [4] Nagoya University, Japan.

The Magellanic Clouds offer an ideal laboratory to study how the interstellar medium evolves and how stars are formed throughout a galaxy at an unrivaled closeness to us. It is known that young populous clusters like R136 are still being formed, making it possible to study cluster formation and its effects to the surrounding medium as well. We have established a catalog of the molecular clouds through the ^{12}CO $J =$ 1–0 observations by NANTEN, a 4 m telescope at Las Campanas Observatory in Chile (Fukui et al. 2008). This catalog contains about 300 GMCs including those with and without massive star or cluster formation. We find that the molecular clouds are classified into three types according to the associated activities of massive star or cluster formation. If a steady state of massive star and cluster formation is a good approximation, by adopting the time scale of the youngest stellar clusters, 10 Myrs, we roughly estimate a lifetime of a GMC of 20-30 Myrs for those with a mass above the completeness limit, $5 \times 10^5 M_\odot$, in the LMC (Kawamura et al. 2009). We have been extending our observations to higher transition lines of CO in submm by ASTE and NANTEN2 (Minamidani et al. 2008, 2011, Mizuno et al. 2010). More detailed structure and properties of the GMCs are obtained by the Mopra observations. These datasets are combined and compared with LVG calculations to derive the density and temperature of clumps. The derived density and temperature are distributed in wide ranges. We suggest that these differences of clump properties represent an evolutionary sequence of GMCs in terms of density increase leading to star formation. Prospects for ALMA observations will also be presented.



Integrated intensity map of ^{12}CO J =1–0 (left), ^{12}CO J =3–2 (middle) and ^{12}CO J =4–3 (right) of one of the most active on-going massive star forming regions, N159 as an example of multi-transition line observations. Lowest contouar levels are 3σ (11, 5, 5 K km s^{-1} for ^{12}CO J =1–0, ^{12}CO J =3–2 and ^{12}CO J =4–3, respectively) level of each observation and increment is 10 K km s^{-1} (Mizuno et al. 2010).

The ASTE Galactic Center Survey in the 350 and 500 GHz Bands

Kunihiko Tanaka[1], Tomoharu Oka[2], Shinji Matsumura[2], Kazuhisa Kamegai[3], Makoto Nagai[4]

[1] Keio University. [2] Keio University. [3] Tokyo University of Science
[4] Tsukuba University

The innermost 200 pc region of our Galaxy, or the Central Molecular Zone (CMZ), is the largest molecular gas reservoir in our Galaxy, containing nearly 10 % of the Galactic molecular mass. The region shows burst-like cluster formation activities in the Sgr A, B and C giant molecular cloud (GMC) complexes. To understand the cluster formation in the CMZ and its history is one of the central issues in the study of the Galactic center. The cluster formation is also potentially related to the formation and evolution of the central supermassive black hole (SMBH), since SMBHs may form from intermediate-mass black holes (IMBHs) which are born in supermassive clusters.

The ASTE Galactic Center key-science project started in 2005, in order to investigate the present and past cluster formation in the CMZ with large scale surveys in the 350 and 500 GHz bands. The most important result from the 350 GHz CO *J*=3–2 and HCN *J*=4–3 observations is discovery of the 'high velocity compact clouds (HVCCs)[4]'. They are small clumps characterized by (1) very large velocity width (ΔV = 50–$100\ \mathrm{km\,s^{-1}}$ in zero-intensity width) indicative of interaction with shock, and (2) huge kinetic energy of internal motion (up to more than 10^{51} ergs) exceeding typical kinetic energy for a supernova-shocked cloud (10^{49-50} ergs). In addition, several HVCCs are found to be associated to superbubble-like structures by follow-up observations with the Nobeyama Radio Observatory 45 m telescope [1]. One of possible origins of these energetic HVCCs is interaction with a series of multiple supernova explosion which took place in a massive cluster with a mass of $> 10^3\ M_\odot$[1,2]. Investigation of internal structure and kinematics of the HVCCs with ALMA observations may prove this hypothesized link between the HVCCs and past cluster formation activity.

The [CI] $^3P_1$-$^3P_0$ mapping in the 500 GHz band was conducted to detect young GMCs related to cluster formation regions[3]. Since C^0 is abundant in an early phase of the molecular cloud formation from atomic gas, the C^0/CO ratio can be used as an indicator of the ages of GMCs. Although the coverage of the observation is limited to a rather narrow area near the Galactic plane, we found several massive clumps with very high [CI]/^{13}CO intensity ratio ($\gtrsim 1$) indicative of their young ages ($\lesssim$ Myr). These [CI] enhanced regions are mainly found near the on-going cluster formation region. This may imply that infall of molecular gas to these regions are taking place, facilitating active star formation there.

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2) Tanaka, K., Oka, T., Nagai, M.,& Kamegai, K. 2009, PASJ, 61, 461
3) Tanaka, K., Oka, T., Matsumura, S., Nagai, M. & Kamegai, K. 2011, ApJL, 743, 39
4) Oka, T., Onodera, Y., Nagai, M., Tanaka, K., Matsumura, S., & Kamegai, K. 2012 ApJS, 201, 14

Maser Astrometry with VERA and the Galaxy's structure

MAREKI HONMA[1]

[1] Mizusawa VLBI Obsevratory, NAOJ, Japan

I will summarize the current status of VERA (VLBI Explortation of Radio Astrometry), a Japanese VLBI array dedicated to maser astrometry. Since 2007, VERA has been conducting astrometric measurements (distances and/or proper motions) for Galactic maser sources within ∼10 kpc from the Sun. In this talk I will present the most-updated VERA's results of maser astrometry, covering both individual maser sources and the structure of the Milky Way Galaxy revealed by maser astrometry, and also discuss the future direction of VLBI activity in Japan in the ALMA era.

Star Formation: From Giant Molecular Clouds to Prestellar Cores

T. ONISHI

Osaka Prefecture University, Japan.

Star formation is a complex process that spans many orders of magnitude in mass and linear scale with a wide variety of extreme environments. Giant Molecular Clouds (GMCs), which are believed to be the formation sites of most stars in galaxies, are formed from diffuse HI clouds possibly via effects of large-scale galactic dynamics and/or energetic events with a size scale of 10 pc to 10 kpc. Stars/clusters form from the densest, gravitationally bound, parsec-scale clumps within the GMCs. Once the gravitational collapse occurs, the typical size evolves from sub-parsec to AU scales in the free-fall time. The physical conditions of each process regulate the nature and rate of star formation, with consequences for planet formation and galaxy evolution. In this presentation, I will review current understanding of star formation revealed by the recent observations also with prospects for ALMA, by focusing on the following subjects; the galactic-scale GMC properties, effects of dynamical interaction of molecular clouds/clumps to the star formation efficiencies, and the nature of the most evolved starless cores just prior to protostar formation.

The distribution and nature of GMCs should regulate the evolution of galaxies via star formation process. Unfortunately, the velocity and spatial crowding in the Milky-Way Galaxy seriously limits our resolved view of GMCs only to the solar vicinity, making it impossible to list all the Galactic GMCs as a complete catalog except for a limited portion toward the outer Galaxy, where crowding is less significant. The superb angular resolutions and sensitivities of ALMA, in combination with the ACA that recovers extended emission, enable us to resolve spatially each GMC or even each clump in many nearby galaxies, which will offer a remarkably detailed view and the dynamics of GMCs in the galaxies and a deeper insight into the galactic evolution.

The star formation activities are not only determined by the mass of molecular clouds but also by the dynamical interactions with the environments. Recent studies are revealing the observational evidences for the enhanced star formation activities due to the interactions; cloud-cloud collisions leading to triggering massive star formation and interaction of dense cores with protostar outflows enhancing local star formation efficiency.

The first protostellar core, which will be detected and confirmed by ALMA, is the first milestone of star formation since it is the first quasi-hydrostatic object formed in the course of star formation and it is obviously crucial to find out the object close to this stage and to test theories of evolution from dense cores to protostars. Although the nature of the first protostellar core itself is very important, the mass distribution of the surrounding gas of inner a few 1000 AU, which should regulate the dynamics of the surrounding gas, must be investigated to diagnose the evolutionary status of dense cores. We would like to stress that the ALMA with the ACA 7m array will be the first instrument for us to be able to look into the detailed mass distribution smaller than 1000 AU scale at a distance of $\sim$140 pc, connecting a single dish scale of $\sim 10''$ to interferometer scale of $\sim 1''$, due to the inclusion of extreme short spacings and to the extremely good surface brightness sensitivity.

Star Formation Revealed by Herschel

PHILIPPE ANDRE[1]

[1] Laboratoire AIM Paris-Saclay, CEA Saclay, France

The Herschel Space Observatory has greatly improved our global understanding of the initial conditions and early phases of star formation. I will present an overview of recent results obtained on the structure of molecular clouds as part of the Herschel Gould Belt survey. The role of filaments in the star formation process and their likely connection to interstellar turbulence will be emphasized. Overall, the Herschel results suggest that it may be possible to understand both the IMF and the global rate of star formation in galaxies by studying the physics of how dense structures (e.g. filaments, cores) form and grow in the ISM of our own Galaxy. Despite an apparent complexity, global star formation may be governed by relatively simple universal laws from filament to galactic scales. With very complementary capabilities to Herschel, ALMA will be a unique tool to probe the rotational fragmentation of individual cores into binary protostars and the formation of extreme objects such as brown dwarfs and massive stars.

Magnetic Fields and Star Formation: The Formation of Cores and Disks

SHANTANU BASU[1]

[1] The University of Western Ontario, Canada.

We review recent work that reveals the important role of non-ideal MHD effects to establish a broad core mass distribution in molecular clouds as well as to permit the formation of protostellar disks. Magnetic fields lead to a broad core mass function since regions with transcritical mass-to-flux ratio produce relatively massive cores. Ambipolar diffusion works agains this trend and allows the formation of many low mass cores as well, but does not eliminate the presence of high mass cores. Once a core begins collapse, magnetic fields are initially dragged inward in a near flux-frozen manner. However, intense magnetic pinching and high density near the protostar leads to a dramatic phase of flux-loss driven by Ohmic dissipation. This allows the formation of a centrifugal disk during the earliest phase of protostellar evolution. However, the cumulative effect of magnetic braking may keep the disk size quite small (< 40 AU) during the Class 0 phase.

Hierarchical Fragmentation of the Orion Molecular Filaments

Satoko Takahashi[1], Paula S. Teixeira[2], Paul T. P. Ho[1,3], and Luis A. Zapata[4]

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[2] Institut für Astrophysik, Universtität Wien, Tuerkenschanzstrasse 17, 1180, Wien, Austria,
[3] Harvard-Smithsonian Center for Astrophysics, 60 Garden Street Cambridge, MA 02138,
[4] Centro de Radioastronomía y Astrofísica, Universidad Nacional Autónoma de México, Morelia, Michoacán 58090, México.

We present high angular resolution and wide-field interferometric continuum observations of the Orion Molecular Cloud (OMC) utilizing the Submilllimeter Array and Expanded Very Large Array (covering 25′/3.1 pc length of the the northern part of the OMC filaments.). We detect more than 50 spatially resolved continuum sources associated with OMC filamentary structures through thermal dust emission. Their estimated masses and sizes range from 0.3 to 5.7 $M_\odot$ and 480 to 4100 AU, respectively, and present a variety of structures. All the detected sources are on the filamentary main ridge ($n_{\mathrm{H_2}} \geq 10^6$ cm^{-3}), and analysis based on the Jeans theorem suggests that these sources are most likely gravitationally unstable. Comparison of multi-wavelength datasets indicates that approximately half of the detected continuum sources are associated with outflows, infrared sources, and ionized jets. These sources show the evolutionary stage from prestellar core to Class 0/I phases. We detect quasi-periodical separations between the OMC sources of ≈0.05 pc. This spatial distribution is part of a larger hierarchical structure, that also includes fragmentation scales of GMCs (≈5°/37 pc), large-scale clumps (≈1.3 pc), small-scale clumps (0.3 pc). This suggests that hierarchical fragmentation operates within the Orion A molecular cloud. Fragmentation spacings are roughly consistent with the local thermal fragmentation length in large-scale clumps (≥0.3 pc), while fragmentation spacings in dense cores measured from the SMA observations is smaller than the local fragmentation length. These smaller observed spacings can be explained by either that helical magnetic field or global filament collapse. In this presentation, we will discuss mechanisms that constrain the fragmentation length within the OMC filament, as well as the time-scale of each of the identified substructures.

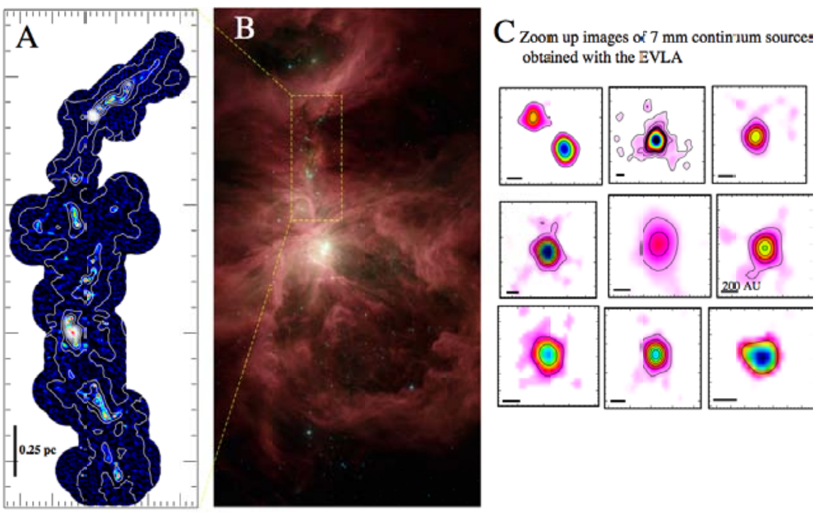

Figure 1: A: The SMA 850 and 1300 μm continuum mosaic image (color) overlaid with the 850 μm continuum image taken with the JCMT/SCUBA (contours referred from Johnstone & Bally 1999). B: The color composite image of OMC cloud obtained with the Spitzer/IRAC bands (Megeath et al.). C: Zoomed up image of the protostellar sources obtained with the EVLA 7 mm continuum.

The origin of the intersteller turbulence and small scale structures of molecular clouds

K. Tachihara[1,2]

[1] Joint ALMA Observatory, Chile
[2] National Astronomical Observatory of Japan

In order to study the origin of the interstellar turbulence, detailed observations in the CO $J = 1$–0 and 3–2 lines have been carried out in an interacting region of a molecular cloud with an H II region by the Nobeyama 45m and ASTE telescopes. As a result, several 1,000 to 10,000 AU scale cloudlets with small velocity dispersion ($\Delta V \sim 0.6$ km s^{-1}) are detected, whose systemic velocities have a relatively large scatter of a few km s^{-1}. It is suggested that the cloud is composed of small-scale dense and cold structures and their overlapping effect makes it appear to be a turbulent entity as a whole. This picture strongly supports the two-phase model of turbulent medium driven by thermal instability proposed previously. On the surface of the present cloud, the turbulence is likely to be driven by thermal instability following ionization shock compression and UV irradiation. Those small scale structures have a relatively high CO line ratio of J =3–2 to 1–0, $1 \leq R_{3-2/1-0} \leq 2$. The large velocity gradient analysis implies that the 0.6 km s^{-1} width component cloudlets have an average density of 10^{3-4} cm^{-3}, which is relatively high at cloud edges, but their masses are only $\leq 0.05\ M_\odot$.

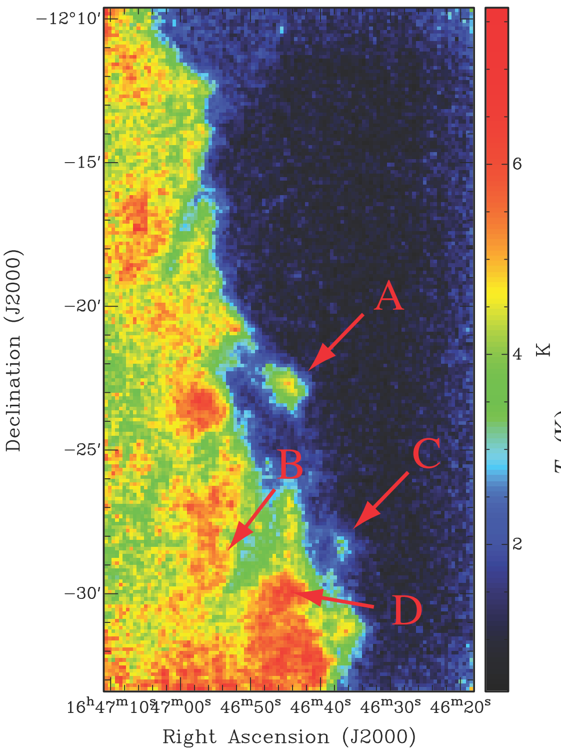

Figure1: Peak T_a map of CO J =1–0 at an interacting cloud surface with an H II region. About several 1,000 to 10,000 AU scale small clumpy (A) and arc-like (C) structures are detected.

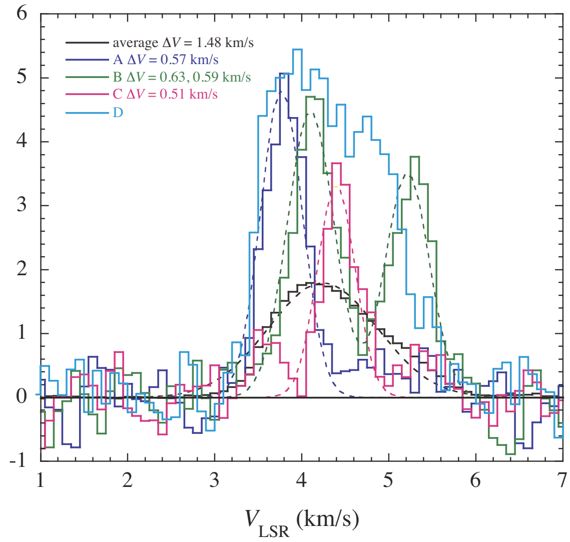

Figure 2: CO J =1–0 spectra obtained at the position designated by the arrows in Fig. 1. The averaged spectrum over the entire observed region are also plotted. The dotted lines denote the best-fit Gaussian profiles.

Tachihara, K., Saigo, K., Higuchi, A. E., Inoue, T., Inutsuka, S., Hackstein, M., Haas, M., Mugrauer, M. 2012, ApJ, 754, 95

Star formation in molecular clouds (theory)

P. HENNEBELLE[1]

[1] Observatoire de Paris and CEA Saclay, France.

I will review some of the theories and numerical simulations of the star formation within molecular clouds that have been proposed along the years. I will particularly focus on the issue of filament and core formation, the relation between the core mass function and the initial mass function and the collapse which leads to the formation of disks and multiple systems.

The Dynamics and Chemistry of Massive Starless Cores

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[1] Dept. of Astronomy, University of Florida, USA
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Progress towards resolving a decade-long debate about how massive stars form can be made by determining if massive starless cores exist in a state of near virial equilibrium. These are the initial conditions invoked by the Core Accretion model of McKee & Tan (2003). Alternatively, the Competitive Accretion model of Bonnell et al. (2001) requires sub-virial conditions. We have identified 4 prime examples of massive ($\sim 50 M_\odot$) cores from mid-infrared (MIR) extinction mapping (Butler & Tan 2009, 2012) of Infrared Dark Clouds. We have found spectacularly high deuterated fractions of N_2H^+ of ∼0.5 in these objects with the IRAM 30m telescope (Fontani et al. 2011). Thus N_2D^+ is expected to be an excellent tracer of the kinematics of these cold, dark cores, where most other molecular tracers are thought to be depleted from the gas phase. We report on ALMA Cycle 0 Compact Configuration Band 6 observations of these 4 cores that probe the N_2D^+(3-2) line on scales from 9 arcsec down to 2.3 arcsec, well-matched to the structures we see in MIR extinction and discuss their implications for massive star formation theories. We also present chemical modeling of these cores, which constrains their ages.

The Millimetre Astronomy Legacy Team 90 GHz Survey (MALT90) and ALMA

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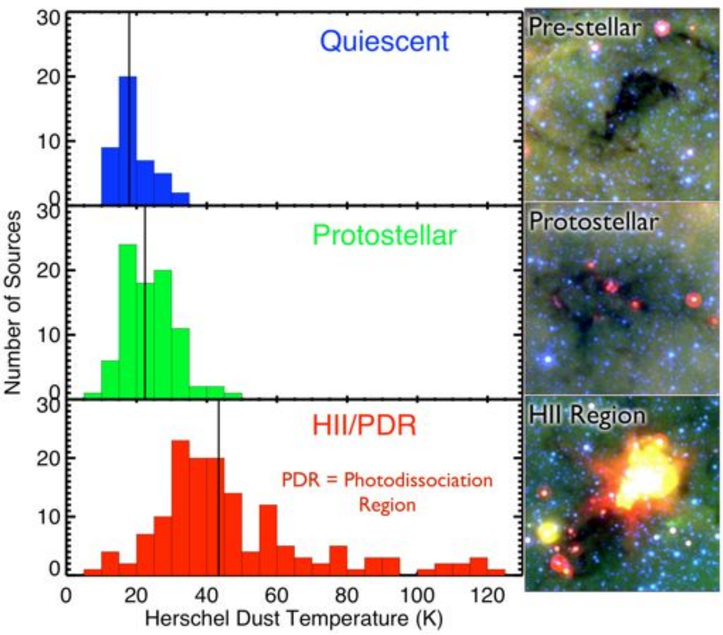
ALMA will revolutionize our understanding of star formation within our galaxy, but before we can use ALMA we need to know where to look. The Millimetre Astronomy Legacy Team 90 GHz (MALT90) Survey is a large international project to make molecular line maps of over 2,000 dense clumps in the Galactic plane. MALT90 serves as a pathfinder mission for ALMA, providing a large public database of dense molecular clumps associated with high-mass star formation. MALT90 provides critical information for planning ALMA observations of these sources, including (1) source velocity, (2) kinematic distance estimates, (3) mass estimates, and (4) chemical/evolutionary stage. A MALT90 source was the basis of a successful ALMA Cycle 0 and the MALT90 source list has been used for several ALMA Cycle 1 proposals. In this talk, I will describe the survey parameters and share early highlights from the survey, including (1) the distribution of high-mass star formation in the Milky Way, (2) a comparison between galactic and extragalactic star-formation relations, and (3) the chemistry of MALT90 clumps. MALT90 will have completed the third year of observations by the date of the conference, and data is publicly available at http://malt90.bu.edu.



MALT90 sources are classified based on their appearance in the mid-infrared. Here, canonical examples of the main classifications (quiescent/prestellar, protostellar, and HII region/photodissociation region) are shown, along with dust temperatures inferred from Herschel Hi-Gal data; the less evolved sources are, on average, colder. MALT90 contains roughly an equal number of sources in each of these three classifications.

A Resolved Keplerian Disk Around One of the Youngest Protostars: Implications for Disk Formation Studies in the ALMA Era

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The formation of proto-planetary disks begins during the earliest phase of the star formation process, while the nascent protostar is still surrounded by a dense envelope of gas and dust. I will present millimeter interferometer observations from CARMA and the SMA at ∼0.3” (42 AU) resolution, revealing an edge-on R ∼ 150 AU proto-planetary disk around the Class 0 protostar L1527 in Taurus. Simultaneous observations of the 13CO (J=2-1) transition are found to trace the disk rotation curve and a protostellar mass of 0.19 +/- 0.04 $M_{\odot}$ is found. The disk structure is constrained through simultaneous radiative transfer modeling of the millimeter data, mid-infrared imaging, and spectral energy distribution, finding properties similar to those of T Tauri disks aside from a large amount of flaring. These observations represent the first direct measurement of protostellar mass from disk rotation and the most definitive evidence for a large disk around a typical Class 0 protostar. This result indicates that large disks can form in the earliest phase of protostellar evolution, contrary to disk formation models which consider magnetic braking. The detection of the disk around L1527 required observations at the highest resolution possible with current interferometers. This lays the ground work for ALMA, which will be needed to make significant gains in the area of disk formation with vastly improved resolution and sensitivity. Most importantly, ALMA’s ability to detect faint molecular lines will enable masses of a large number of Class 0 protostars to be measured for the first time.

Keplerian Circumbinary Disk and Accretion Streams around the Protostellar Binary System L1551 NE

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[2] Joint ALMA Observatory, Chile.
[3] University of Hong Kong, Hong Kong.
[4] National Astronomical Observatory, Japan.
[5] Chiba University, Japan.
[6] Hosei University, Japan.

In the present talk we will show our recent SMA results of L1551 NE, a Class I protostellar binary at a projected separation of ~73 AU (Source A at the south-east and Source B north-west), in the 0.9-mm dust continuum emission and the ^{13}CO (3–2) and C^{18}O (3–2) line emission at a spatial resolution of ~120×80 AU. The 0.9-mm dust-continuum image (Fig.1 left) shows three distinct peaks. The brightest component at center is closely coincident with Source A, and exhibits an extension towards B; this component can be decomposed into two unresolved sources, indicating very compact circumstellar disks, coincident with Source A and B. The outer northern and southern continuum components are located almost symmetrically with respect to the central component, and have tilted-U shapes as indicated by the dashed curves, suggestive of a r ~300 AU circumbinary disk with an inner (r ~140 AU) clearing. The ^{13}CO and C^{18}O images confirm that the circumbinary continuum feature is indeed a rotating disk (Fig.1 right); furthermore, the C^{18}O channel maps can be well modeled by a geometrically thin disk exhibiting Keplerian rotation with a central stellar mass of 0.8 $M_\odot$. These observational results, *i.e.*, circumstellar disks plus a Keplerian circumbinary disk with an inner clearing, match well our theoretical simulation of accretion onto protostellar binaries from surrounding circumbinary disks. We will discuss the possibility to directly image the theoretically-predicted "spiral accretion streams" that connect the surrounding circumbinary disk to the individual circumstellar disks in L1551 NE with the ALMA observation.

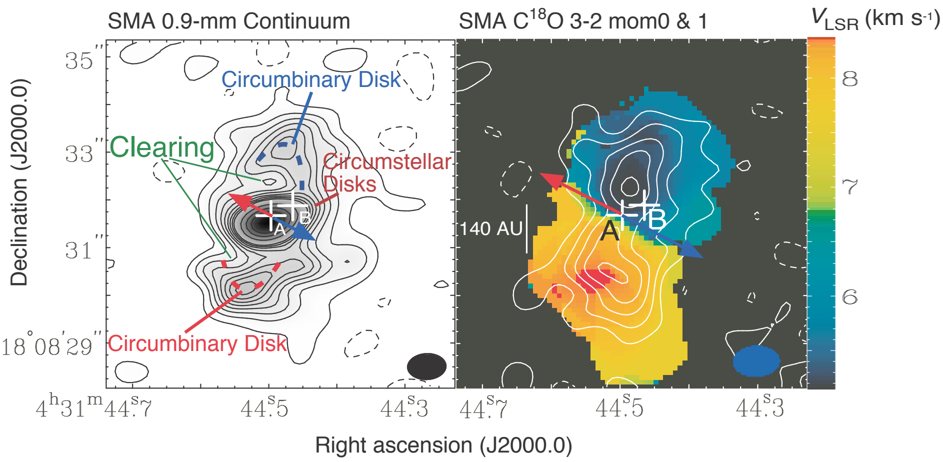

Figure 1: (*Left*) Our (Takakuwa et al. 2012) 0.9-mm continuum image of L1551 NE as observed with the SMA. Contour levels are from 3σ in steps of 4σ until 35σ, and then in steps of 20σ until 115σ (1σ = 3 mJy beam^{-1}). Crosses indicate the positions of the two protostars, named Source A and B, of L1551 NE. A filled ellipse at the bottom-right corner shows the synthesized beam (0.″80 × 0.″54; P.A. = -87°). Dashed curves delineate tilted U-shaped features, and arrows show the direction of the [Fe II] jets driven by Source A. Individual features are labelled as Circumbinary Disk, Circumstellar Disks, or Clearing. (*Right*) Integrated-intensity (white contours) superposed on the intensity-weighted mean-velocity (color scale) maps of the C^{18}O (J = 3–2) emission as observed also with the SMA. Contour levels are from 2σ in steps of 2σ (1σ = 0.17 Jy beam^{-1} km s^{-1}). A filled ellipse at the bottom-right corner indicates the synthesized beam (0.″95 × 0.″66; P.A. = -88°).

Keplerian Disks around Protostars: from NMA to SMA and ALMA

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Keplerian disks have been considered to be formed as by-products of star formation. It is, indeed, true that Keplerian disks are ubiquitous around pre-main-sequence stars. Since they are the most probable site of planet formation, they are called protoplanetary disks, and have been observationally and theoretically studied in the last two decades. Nevertheless, the formation and evolution process of these Keplerian disks is still poorly understood. Some theoretical simulations suggest even pictures where it is difficult for Keplerian disks to be formed around protostars because of magnetic fields. In order to understand the formation and evolution process of Keplerian disks around protostars observationally, the key is to unambiguously identify Keplerian disks around protostars deeply embedded in dynamically infalling and slowly rotating envelopes.

We have been observing protostars deeply embedded in infalling envelopes with NMA and SMA, suggesting possible transition from infalling motions to Keplerian motions In the inner regions of infalling envelopes. In this talk, we will briefly review NMA observations of infalling envelopes around protostars, and will present recent SMA observations demonstrating possible formation and evolution of Kepelrian disks in these infalling envelopes. In addition, results of approved cycle 0 ALMA observations of the innermost envelopes will be also discussed if they are available, including a possibility to derive dynamical masses of protostars using Kepler motions of their disks.

The Structure of Protoplanetary Disks as inferred from mm/submm Interferometry

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In the early nineties, mm/submm arrays begun to routinely image gas and dust disks orbiting low-mass TTauri and young intermediate-mass stars. The first images were strongly limited in sensitivity and angular resolution and did not allow observers to perform detailed comparisons with models. Moreover one key parameter for planet formation, the disk mass distribution, remains difficult to measure because it relies on indirect tracers such as the dust thermal emission or the molecular lines. The interpretation of these data suffer from different uncertainties. However, thanks to recent upgrades of mm/submm interferometers associated to the heterodyne detection which provides very high spectral resolutions (of the order of 0.2 km/s or better), the first quantitative studies of the physical structure (temperature, density, turbulence...) and kinematics of gas-rich protoplanetary disks have been made possible. One can consider that the thermal and density structures are basically understood even if there are several discrepancies between model predictions and observations which must be solved before constraining models of planet formation. The most recent observations performed at high angular resolution also reveal that the geometry is more complex than that of a simple flaring disk, as usually assumed by most disk models. Several images show the presence of inner cavities and inhomogeneities in the gas and dust distributions. In a few cases, departure to pure Keplerian rotation has also been observed.

In this review, I will summarize our current understanding of the physical structure of disks as inferred from recent dust continuum maps and molecular spectro-imaging obtained at high angular resolution ($\sim 0.5''$) on a few proto-typical objects such as AB Auriga, GG Tau or DM Tau... I will then discuss these results in light with the advent of ALMA.

The Structures of Protoplanetary Disks

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Direct observations of the reservoirs of planet-building material – the disks around young stars – play a critical role in developing theoretical models of the planet formation process. For more than 30 years, radio/mm/sub-mm interferometry measurements have held the most promise for groundbreaking work in this field: they provide high-resolution access to a wealth of molecular emission lines and an optically thin dust continuum that serve as unique probes of disk structures (the spatial distributions of densities, temperatures, etc.). After a brief overview of the methodology, I review some key aspects of what we have learned about disk structures and comment on their implications for models of disk evolution and planet formation. Building on those results, I will highlight some of the current (and future) directions being pursued in this field, including the potential signatures of planet-disk interactions (the so-called "transition" disks) and some tentative evidence for the growth and migration (radial drift) of solid particles.

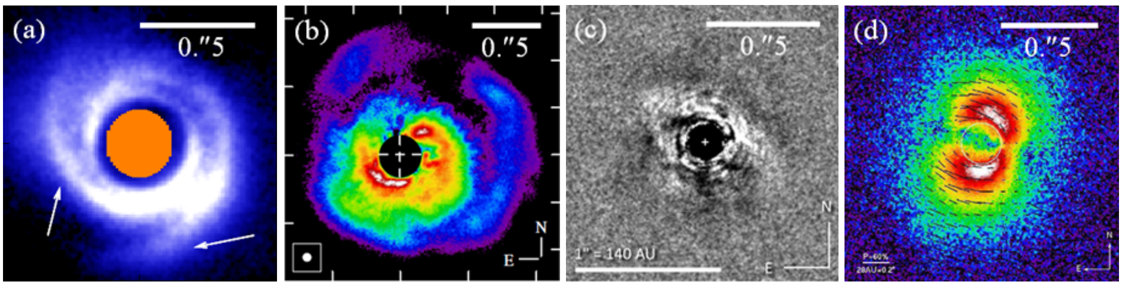
High Angular Resolution Infrared Observations of Protoplanetary Disks

M. Fukagawa[1], J. Hashimoto[2], M. Tamura[2], SEEDS/HiCIAO/AO188 teams

[1] Osaka University, Japan.
[2] National Astronomical Observatory, Japan

Observations of protoplanetary disks are essential to understand planet building process since they provide realistic initial conditions as well as insights into new-born planets through disk-planet dynamical interaction. We present the recent effort to directly image those disks in scattered light with high angular resolution, focusing on the near-infrared results obtained with Subaru. Scattered-light observations are complementary with longer-wavelength studies as they can provide the information on smaller grains in disks, thus useful to discuss such as grain growth and dust transport that can be either the basic step toward or the consequence of planet-forming activity. In fact, the comparable angular resolution will be achieved in submillimeter soon with ALMA, and multi-wavelength study will become more important for comprehensive understanding of disks.

As a part of Strategic Exploration of Exoplanets and Disks with Subaru (SEEDS), we have observed more than 40 T Tauri and Herbig Ae/Fe stars. Our targets include transitional systems showing the dips in the mid-infrared SEDs and/or the resolved cavities in submillimeter. We have primarily employed the technique of polarization differential imaging (PDI) combined with adaptive optics, which is powerful to achieve high contrast by extracting the scattered light from the disk while suppressing the unpolarized stellar light. The PDI observations indeed enabled us to look at the inner region, as close as 10 AU in radius, with the typical angular resolution of 0.06 arcsec, corresponding to less than 10 AU in nearby star-forming regions (e.g., Hashimoto et al. 2011, Kusakabe et al. 2012, Tanii et al. 2012). Consequently, the SEEDS imaging has newly uncovered rich structures such as spiral arms, inner holes, and gaps for transitional systems. One of the highlights is the discovery of two spiral arms in the submillimeter cavity for SAO 206462, which can be explained by presence of possible planets (Muto et al. 2012). We will overview the results of scattered-light imaging and discuss how to exploit the synergy with submillimeter/millimeter observations.



Images of protoplanetary disks at 1.6 micron obtained with Subaru/HiCIAO+AO188. (a) SAO 206462 (Muto et al. 2012), (b) AB Aur (Hashimoto et al. 2011), (c) LkCa 15 (Thalmann et al. 2010), (d) UX Tau A (Tanii et al. 2012). Note that the images show the *polarized* intensity except for LkCa 15.

References:

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Kusakabe, N., Grady, C. A., Sitko, M. L., et al. 2012, ApJ, 753, 153
Muto, T., Grady, C. A., Hashimoto, J., et al. 2012, ApJL, 748, L22
Tanii, R., Itoh, Y., Kudo, T., et al. 2012, accepted in PASJ
Thalmann, C., Grady, C. A., Goto, M., et al. 2010, ApJL, 718, L87

SEEDS: Direct Imaging of Exoplanets and Their Forming Disks with the Subaru Telescope

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[1] NAOJ, Exoplanet Project Office, Tokyo, Japan.

SEEDS (Strategic Explorations of Exoplanets and Disks with Subaru) is the first Subaru Strategic Program, whose aim is to conduct a direct imaging survey for giant planets as well as protoplanetary/debris disks at a few to a few tens of AU region around 500 nearby solar-type or more massive young stars devoting 120 Subaru nights for 5 years. The survey employs the new high-contrast NIR instrument HiCIAO, a successor of the previous NIR coronagraph camera CIAO for the Subaru Telescope. We describe the outline of this survey and present its first 2 years results including detection of the most unequivocal and low-mass planet via direct imaging and discovery of unprecedentedly detailed structures of protoplanetary disks.

References:

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Tamura, M. 2009, in AIP Conf. Proc. 1158, Exoplanets and Disks: Their Formation and Diversity, ed. T. Usuda, M. Ishii, & M. Tamura (Melville, NY: AIP), 11
Thalmann, C. et al. 2009, ApJ, 707, L123
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Observational constraints on disk evolution and the initial steps towards planet formation

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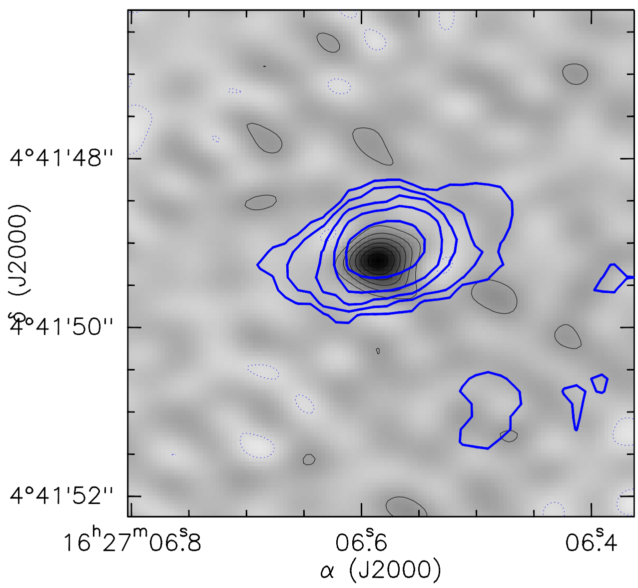
Planet formation is expected to occur in circumstellar disks during the first few Myrs of the stellar pre main sequence evolution. In the core accretion paradigm of planet formation, the solid component of the disks (the dust) grows and coagulate to form planetesimals and rocky cores of planets. We have been studying extensively the grain growth process in nearby star forming regions protoplanetary disks. As a tool we use submillimetre and centimeter wave emission from the dust in the disk midplane, that depends on the opacity per gram of dust, which in turn is related to the composition and size of dust grains. We find evidence for an early growth of dust and a relatively long survival time for large grains in disks. Our results are at odds with simple model expectations that predict rapid migration and depletion of the large grains population in disks: observations show that large grains are retained in the outer disks for relatively long timescales (few to several Myrs). We discuss possible mechanisms to solve the discrepancies between models and observations. We present also the results of new observational tests with ALMA and other millimetre arrays that provide critical constraints on the model assumptions and on the initial conditions for planet formation. In particular we will report on the results of an ALMA Cycle 0 project aimed at constraining dust evolution in disks around young Brown Dwarfs. Young BDs systems offer the opportunity to test disk evolution models in an environment that is significantly different than around solar-mass stars and thus provide critical tests of the validity of dust evolution models. At the time of writing of this abstract, we have just received the first LMA dataset on one of our brown dwarfs disks. We measure with high reliability the disk mass and constrain the grain properties with continuum measurements at 850um and 3mm with ALMA. In addition, we confirm the detection of a molecular outflow from our target (which was previously observed with the SMA) and serendipitously detect molecular gas from the disk. While the analysis is ongoing at the moment, we can already confirm that the disk around this object is relatively large and massive with strong evidence for grain growth. These results impose strong constraints on the formation theories of BDs and disk/dust evolution models.



ALMA-Cycle 0 observations of the bright disk around the young BD ρ–Oph 102. The greyscale and thin black contour show the 340 GHz continuum emission, the thick blue contours show the CO(3-2) integrated line emission. These data has just received at the time of writing the present abstract and, while the analysis is still ongoing, we confirm the continuum detection of the disk, derive an estimate of the continuum spectral index (which was the scientific goal of the Cycle 0 proposal) and serendipitously detect, for the first time, molecular gas emission in a disk associated with a young BD.

Sub-mm studies of debris disks

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Several hundred nearby main sequence stars are known to be surrounded by dusty debris disks that are usually considered to be extrasolar analogues to the Kuiper belt. Sub-mm studies play a crucial role in understanding the disks, since they trace large (mm-sized) dust that is much less affected by radiation and stellar wind forces than the smaller (micron-sized) dust that is traced by far-IR and optical observations. Thus sub-mm observations are crucial to provide a more accurate measure of the mass of parent planetesimals in the disk, and to trace the location of those planetesimals, as well as giving a constraint on the size distribution of the dust. Here I will review the current status of knowledge of the debris disk population resulting from two complementary surveys: DEBRIS, a key programme on Herschel that searched for far-IR emission from dust around the nearest ∼100 stars of each spectral type A, F, G, K and M, and SONS, a legacy survey on JCMT using SCUBA2 to search for sub-mm emission from known debris disks. This will be used to place the most recent ALMA observations of debris disks into context, and to outline what we can expect to learn from ALMA observations of these disks about their planetary systems in the coming few years.

Resolved Millimeter Emission Belts in the β Pictoris and AU Microscopii Debris Disks

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Debris disks around young main-sequence stars provide a window into formation of planetary systems. Imaging at millimeter wavelengths plays a key role because emission at these long wavelengths is dominated by large grains that are minimally affected by non-gravitational forces and therefore trace best the underlying population of dust-producing planetesimals. We SMA observations that resolve the millimeter emission from the debris disks surrounding the nearby ~ 10 Myr-old stars β Pictoris and AU Microscopii. For both systems, which are viewed nearly edge-on, the observations reveal a belt of emission surrounding the star with the same geometry as the more extended scattered light imaged at optical wavelengths. Simple models show the locations of these millimeter belts are consistent with reservoirs of planetesimals ("birth rings") previously invoked to explain the detailed shape of the scattered light surface brightness profiles through size-dependent dust dynamics. We have an ALMA Cycle 0 program in the queue to image the AU Microscopii system at substantially better sensitivity and higher angular resolution than the SMA, and we will present these results, if available. While the SMA shows the global disk structure, ALMA has the potential to reveal asymmetries and substructure indicative of perturbations from unseen planets.

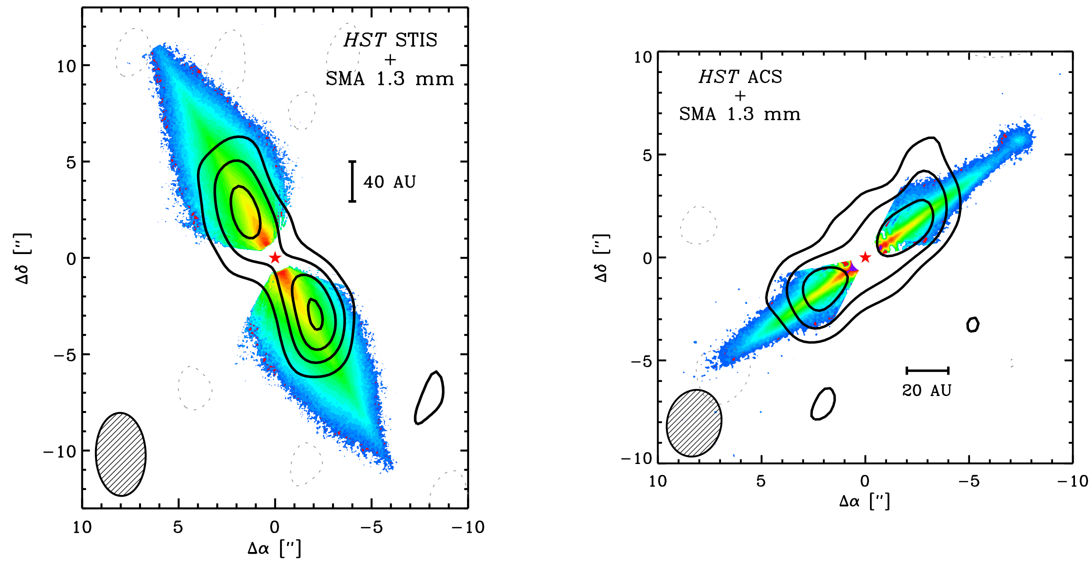

Figure 1: SMA images of the 1.3 millimeter emission in contours overlayed on images of optical scattered light from the Hubble Space Telescope for the debris disks around *(left)* β Pic (Wilner et al. 2011) and *(right)* AU Mic (Wilner et al. 2012). The contour levels are $-2, 2, 4, 6, \ldots \times$ the rms noise of 0.6 mJy and 0.4 mJy, respectively. The ellipses in the lower left corners represent the $\sim 3''$ synthesized beams. The star symbols show the locations of the stars.

References:
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New trends in astrochemistry in the ALMA era

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Astrochemistry is entering a golden age, with new powerful telescopes from radio to infrared wavelengths opening up studies of molecules from the smallest < 1 AU scales in protoplanetary disks to the largest kpc scales in high redshift star-forming galaxies. In this talk, an overview will be given of recent developments in the field, including the wealth of data on water and other molecules from Herschel and the surprisingly rich near- and mid-infrared spectra of disks. Recent results from single dish and millimeter interferometers on simple and complex molecules will be summarized in the context of models of the physical and chemical evolution of star- and planet-forming regions. The promise of ALMA in revolutionizing the field will be illustrated with early results, and the need for further laboratory work emphasized.

Pre-stellar Cores and Infrared Dark Clouds

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The initial conditions in the process of star and planet formation are to be found in pre-stellar cores, which are dense ($n_H > 10^5$ cm^{-3}), cold ($T \leq 10$ K), centrally concentrated $\simeq$0.1 pc regions of molecular clouds, undergoing gravitational contraction. A good knowledge of the physical structure and kinematics of pre-stellar cores is needed to put constraints on theories of star and planet formation. This implies a good understanding of the pre-stellar core chemical structure, as spectral line profiles provide the best diagnostics of the physical properties across the core and the only diagnostics of the dynamics. Because of their simple structure and quiescent nature, pre-stellar cores are also ideal laboratories where to measure key astrophysical processes and parameters. In this talk I will review our current understanding of pre-stellar cores in low-mass star forming regions, show recent Herschel observations and describe how ALMA will soon unveil the still unexplored central few hundreds AU of pre-stellar cores, the future stellar cradles. I'll then move to Infrared Dark Clouds (IRDCs), which host the earliest stages in the process of high-mass star and stellar cluster formation. I will show that the molecular tools used to study nearby pre-stellar cores have provided a way to unveil starless massive cores within IRDCs and test star formation theories. The crucial role of ALMA in this study will be highlighted.

Molecules in Bipolar Outflows from Young Stellar Objects

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Bipolar outflows from young stellar objects represent some of the best laboratories to study shock chemistry in the interstellar medium. Recent observations show that a number of molecular species suffer order-of-magnitude abundance enhancements in the outflow gas, likely due to a combination of dust-mantle disruption and high-temperature gas chemistry. The study of these enhanced species is of great interest to characterize shock chemistry. It also offers a highly selective tool to trace the interaction between the outflow and the cloud, which is necessary to elucidate the still mysterious nature of the outflow driving wind. Here we will review some of the recent progress in the study of the molecular composition of bipolar outflows, with emphasis on the tracers most relevant for shock chemistry and on the new data from the Herschel Space Observatory.

Chemical Diversity of Low-Mass Star-Forming Cores: Class 0 to Class I

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In formation of a solar-type star by gravitational collapse of a dense core, molecules and dust particles contained in a parent core are processed through various chemical reactions both in the gas and solid phases, a part of which would be delivered to a protoplanetary disk and eventually to planets. They may be related to presolar materials found in meteorites. Thus, tracing chemical evolution of a prestellar/protostellar core along formation and evolution of a solar-type protostar is of fundamental importance in order to explore a relation between interstellar chemistry and chemistry of our solar system.

So far, chemical composition of prestellar cores and Class 0 sources has been studied in detail by radioastronomical observations. In these studies, chemical diversity has clearly been established for the Class 0 sources. One distinct case is the hot corino chemistry characterized by rich existence of ′saturated′ complex organic molecules (COMs) such as $HCOOCH_3$ and C_2H_5CN, whereas the other is the warm carbon-chain chemistry (WCCC) characterized by extraordinary richness of ′unsaturated′ complex organic molecules such as carbon-chain molecules. We proposed that such chemical diversity would originate from the difference of the duration time of a starless-core phase (Sakai et al. 2009; 2011).

Then, an apparent question is whether the diversity is seen in more evolved (i.e.Class I and II) stages. Although the relation between hot corinos and protostellar disks is still unknown, saturated COMs are acturally distributed within a few 100 AU region around the protostar. Furthermore, Pineda et al. (2012) have recently found the inverse P Cygni profile of the $HCOOCH_3$ lines toward the hot corino IRAS16293-2422, by using the ALMA SV data. This is a clear evidence that saturated COMs exist in the infalling material near the Class 0 protostar. On the other hand, we recently found that carbon-chain molecules also exist in the closest vicinity of the protostar (¡ 500 AU) in the WCCC sources. Thus, the chemical variation should be delivered to the protoplanetary disks. Its detailed processes are needed to be clarified.

With this motivation, we have extensively searched for Class I sources showing the WCCC feature, and have finally found a potential candidate. It is IRAS04365+2535 in TMC-1A. Strong high excitation lines of carbon-chain molecules with a peculiar velocity structure have been found toward this source. The lines appear at 5.9 km/s, which is different from the systemic velocity of the parent cloud core (6.4 km/s). The lines show central condensation around the protostar, and can better be seen in higher excitation lines. It seems most likely that the 5.9 km/s component traces a warm and dense part near the protostar, where the carbon-chain molecules are abundant. The velocity shift of the 5.9 km/s component would be explained as a remnant of the rotating envelope structure or a part of the inverse P Cygni profile originating from the infalling motion. By high spatial resolution observations toward the Class 0 and Class I WCCC sources with ALMA, we would like to explore how the two distinct chemistry in the Class 0 stage evolve into the Class I stage. This will provide us an important clue for a thorough understanding of chemical evolution from protostellar cores to protoplanetary disks. In the presentation, I would like to discuss the evolution of the WCCC sources from Class 0 to Class I, hopefully with the ALMA cycle 0 data.

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Chemistry in Star-Forming Regions: Herschel Looking towards ALMA

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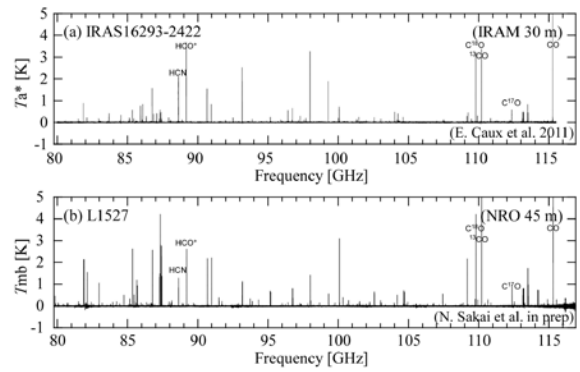
In this talk I will present a census of results from the Herschel Space Observatory regarding molecules in space. With ALMA coming online I will frame the talk as a discussion of what the Herschel results are telling us about chemsitry in space and how we can use ALMA to look deeper. Key aspects to be discussed include the chemistry of organics in hot cores, simple molecules in the interstellar medium and dense cores, to hot gas in photodissociation i regions and protostars. A part of this talk will be directed towards presenting some of the near complete spectral scans obtained by Herschel covering from 460 GHz to 1.9 THz with 1 MHz resolution. The plethora of data available in the Herchel data sets presents challenges in analysis. I will discuss the techniques applied to model the entire spectrum at once and how these may change when confronting ALMA data.

Nobeyama 45 m telescope legacy project: Line survey

Takano, S. (NRO/GUAS), Aikawa, Y. (Kobe U.), Chen, V. (NTHU), Hirano, N. (ASIAA), Hirota, T. (NAO), Kamegai, K. (Tokyo U. Sci.), Kobayashi, K. (Toyama U.), Kohno, K. (U. Tokyo), Kuan, Y-J. (NTNU), Liu, S.-Y. (ASIAA), Nakajima, T. (Nagoya U.), Ohashi, N. (NAO), Ohishi, M. (NAO), Ozeki, H. (Toho U.), Sakai, N. (U. Tokyo), Sakai, T. (U. Tokyo), Shiba, S. (U. Tokyo), Su, Y.-N. (ASIAA), Sugimura, M. (U. Tokyo), Takakuwa, S. (ASIAA), Umemoto, T. (NAO), Wang, K.-S. (U. Leiden), Watanabe, Y. (U. Tokyo), Yamada, M. (ASIAA), Yamaguchi, T. (U. Tokyo), Yamamoto, S. (U. Tokyo), Zhang, Q.-Z. (CfA)

Line surveys are of fundamental importance in astronomy not only for complete understanding of molecular abundances, but also for finding out new observational tools (spectral lines) probing interstellar medium. We carried out a new line survey project at the 3 mm region. The target sources are the low-mass star-forming region in L1527, the shocked region in L1157 B1, the infrared dark clouds G28.34+0.06, and the external galaxies NGC 1068, NGC 253, and IC 342.

The preliminary main results are as follows. (1) L1527: This is an interesting star-forming region with high abundances of carbon-chain molecules (Sakai et al. 2008). The survey was done from 80 to 117 GHz. We detected many lines from 39 species including various carbon-chain molecules, isotopic species (D, ^{13}C) of some carbon-chain molecules, and unidentified species (see Figure). (2) L1157 B1: This is a prominent region of interactions between a molecular outflow from the protostar and ambient clouds (Umemoto et al. 1992 and Mikami et al. 1992). This is an ideal region to study shock chemistry. The survey was finished from 78.1 to 115.5 GHz. We detected 130 lines from 44 species including CH_3CHO, CH_2DOH, carbon-chains, and PN (Sugimura et al. 2011, Yamaguchi et al. 2011, 2012). (3) G28.34+0.06 (possible high-mass star-forming regions): Three interesting positions called MM1, MM4, and MM9 were selected, and the survey almost covered from 80 to 110 GHz. Toward MM1 and MM4 line wings were found in SiO and so on. These wings indicate outflow activities. In addition, CH_3CHO is detected only in MM1 and MM4, though N_2D^+ was detected only in MM9. Based on these results, MM1 and MM4 are thought to be active and more evolved objects. (4) NGC 1068 is a nearby galaxy with X-ray radiation from AGN, and NGC 253 and IC 342 are also nearby galaxies with prototypical starbursts. The survey was finished from 85 to 116 GHz. We detected 21-23 species depending on the galaxies including several new detections (e.g. cyclic-C_3H_2 and C_2H in NGC 1068, Nakajima et al. 2011). The intensities of HCN and CN relative to ^{13}CO are significantly strong in NGC 1068 compared to those in NGC 253 and IC 342.



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Shocks in Low-Mass Protostellar Environments:
Present Lessons and Future Observations

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Herschel and the large ground-based millimeter radiotelescopes have revealed the important role of shocks in the chemical evolution of star forming regions. This is well illustrated by the spectral survey of the protostellar shock L1157-B1 from $672\mu m$ up to $55\mu m$, carried out with Herschel, as part of the CHESS key project, and from 80 to 350 GHz with the IRAM 30m telescope. The unprecedented sensitivity of these instruments brings new insight both on the molecular content and the physical conditions of this long studied region, thanks to the detection of hydrides (H_2O, HCl,) and of the high-excitation lines of heavy molecules (CO, CS, HCO^+, HCN,...). With the help of complementary molecular emission maps from the Plateau de Bure interferometer, multi-transition analysis of the line profiles reveals the presence of multiple emission components [1,5,6,7] of differing excitation conditions and constrains the formation/destruction scenarios of various molecular species [2,3,4] including water, in relation with shock models, while unveiling the chemical history of the cloud. I will discuss the new view on the physical and chemical structure of protostellar bowshocks which emerges from these observations, the role of ALMA and NOEMA as well as the need for future complementary instruments to get a coherent picture of protostellar shocks.

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Chemical Models of Star Forming Cores

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[1] Kobe University, Japan

In this talk, I will review chemical models of low-mass star forming cores including our own work. Chemistry in molecular clouds are not in equilibrium. Molecular abundances in star forming cores change not only with physical conditions in cores but also with time.

In prestellar cores, temperature stays almost constant while the gas density increases. Three chemical phenomena are observed in this cold phase: molecular depletion, chemical fractionation, and deuterium enrichment. As the gas density increases at the core center, collisional timescale of gaseous species and grains shortens and molecules are frozen onto grain surfaces. While CO depletion is often observed towards prestellar cores, depletion of N-bearing species are less frequently found, which is called chemical fractionation. Since the conversion of N atom to N_2 and NH_3 is slower than the CO formation, N-bearing species are more resilient against depletion. Molecular D/H ratio, XD/XH, becomes larger than the elemental D/H ratio in prestellar cores. Since the zero-point energy of deuterated species are smaller than their normal isotope counter parts, exchange reactions such as H_3^+ + HD $\rightarrow$ H_2D^+ + H_2 are exothermic. The high D/H ratios achieved by the exchange reactions propagate to other molecules via chemical reactions. CO depletion further enhances the deuterium enrichment, because CO is the dominant reactant with H_2D^+.[1][2]

The collapse timescale of prestellar cores depends on the initial ratios of thermal/turbulent/magnetic pressure to gravitational energy. Since chemical timescales, such as adsorption timescale of gas particle onto grains, are comparable to the collapse timescale, molecular abundances in cores vary depending on the collapse timescale. So far, a variety of molecular abundances are found in cores with similar central densities; it could originate in the pressure to gravity ratio in the cores.[2][3]

As the core contraction proceeds, compressional heating eventually overwhelms radiative cooling, and the core starts to warm up. The first core is formed when the contraction in the central region is temporally halted by the pressure gradient. As the temperature exceeds 2000 K at the core center, H_2 is dissociated, and the center of the first core collapses again to form a protostar.[4] Temperature of the infalling gas from the envelope increases as it approaches the central region. Grain-surface reactions of adsorbed molecules occur in this warm-up phase as well as in prestellar phase. Hydrogenation is efficient at $T \leq 20$ K, whereas radicals can react with each other to form complex organic molecules (COMs) at $T \geq 30$ K. Grain-surface species are sublimated to the gas phase and re-start gas-phase reactions; i.e. unsaturated carbon chains are from sublimated methane. Our model calculation predicts that both COMs and unsaturated carbon chains increases as the warm region extends outwards. These newly formed molecules in protostellar phase inherit high D/H ratio of their mother molecule, which originates in cold prestellar phase.[5][6]

3D hydrodynamics simulations show that the first core is oblate. While the central region collapse to form a protostar, the rest of the first core will evolve to be the protoplanetary disks. I will present molecular abundances in the core harboring the first core and briefly discuss how the molecules accreted from the envelope evolve in the protoplanetary disks.[7][8]

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Observations of chemistry in protoplanetary surrounding low-mass stars

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Understanding the structure and evolution of disks surrounding young low-mass stars is one of the key issues to study the process of planet formation. Nevertheless the overall properties of those disks are not yet well constrained by observations. Several other molecules than CO and its isotopologues have been detected in the outer part of the disks in the millimeter domain : HCO^+, $H^{13}CO^+$, DCO^+, H_2CO, H_2O, CS, C_2H, N_2H^+, HCN, HNC, CN, DCN, and very recently HC_3N. This molecular tracers bring some constraints on the disk physical structure since they sample different physical conditions.

In this talk I will present recent results obtained thanks to molecular line observations (including some ALMA results if available), and confront them to models of proto-planetary disks, in particular to the the layered structure that is predictied by all chemical models so far.

Diagnosing gas dispersal processes in protoplanetary disks

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Thanks to the recent development of (sub)mm and infrared instruments, it has become possible to detect transition lines of various kinds of molecular species in protoplanetary disks. ALMA will be able to detect molecular lines from the inner disks, which will reveal detailed physical and chemical structure of planet-forming region in the disks.

In this work we have studied the chemical structure of protoplanetary disks using a comprehensive astrochemical reaction network extracted from UMIST Rate06, based on a detailed model for the gas and dust temperature and density profiles, which takes into account UV and X-ray irradiation from stars. Here we especially focus on molecular lines which could useful to diagnose physical processes related to gas dispersal from the disks; molecular line tracers of (i) ionization degree near the midplane and (ii) gas temperature profiles in the surface layer. The former is related to magnetorotationally unstable regions and gas accretion towards the central star, and the latter is connected to photoevaporation process; keys to understanding planet-formation in the disks. Our results indicate that HCO^+ 1-0/$C^{18}O$ 1-0 line ratio will be useful to measure ionization degree near the disk midplane, and our model suggests that the disk surface is magnetorotationally unstable due to ionization by UV and X-ray irradiation, while disk midplane is stabilized due to Ohmic dissipation (<20AU) and ambipolar diffusion/ Hall effect (<200AU). Also, we find that multi-line observations of CN and HCN will reveal gas temperature gradient in the disk surface, and CN lines will trace the gas temperature of photoevaporating region of an externally irradiated disk, where thermal energy dominates the gravitational energy of the central star. Observations of these simple molecular lines by ALMA will be useful to diagnose gas dispersal processes in the disks.

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Planetary Atmospheres at High Resolution

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The long millimeter through submillimeter bands are particularly well suited for studying the wide variety of planetary atmospheres in our solar system. Temperatures ranging from a few 10s to hundreds of degrees, coupled with typically high densities (relative to the ISM) mean that thermal 'continuum' emission can be strong and molecular rotational transitions can be well-populated. Large bodies (Jovian and terrestrial planets) can be reasonably well studied by current interferometers, yet many smaller bodies with atmospheres can only be crudely studied, primarily due to lack of sensitivity. Figure 1 presents roughly the current 'dynamic scale' available for studying atmospheres in our solar system (∼50 in the mm/submm). Newly powerful interferometers such as the EVLA and ALMA will usher in a new era of planetary atmospheric exploration. The vast sensitivity and spatial resolution of these arrays, especially with ALMA, will increase this dynamic scale substantially. New science allowed will range from detailed mapping of HDO, ClO, and sulfur species in the mesosphere of Venus and PH3 and H2S in the upper tropospheres of the gas and ice giants, high SNR mapping of winds on Mars, Neptune and Titan, down to spectroscopic imaging of volcanic eruptions within the tenuous atmosphere on Io, resolved imaging of CO and other species in the atmosphere of Pluto, and even potentially detection of the plumes of Enceladus.

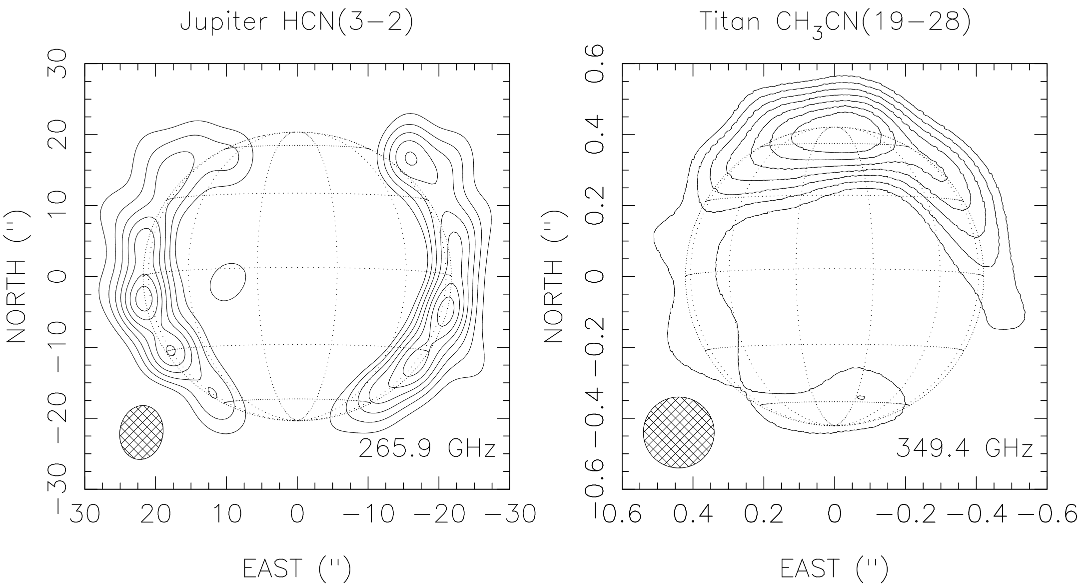

Fig. 1. Demonstration of the range of spatial scales currently available in planetary astronomy at mm/submm frequencies. These images differ in apparent spatial scale by ~ 50. (*left*) Submillimeter Array (SMA) imaging of stratospheric HCN on Jupiter (eq. diameter $43''$, resolution $\sim 7''$; 27 April 2007). The HCN is a relic of the Comet Shoemake-Levy 9 impacts in July 1995. The broad mid- to low-latitude distribution implies latitudinal mixing, but the distinct lack of HCN in the polar regions is suggestive of a polar vortex, which entrains HCN and transports it downward where it is destroyed (courtesy R. Moreno). (*right*) SMA imaging of stratospheric CH_3CN on Titan (eq. diameter $0.84''$, resolution $\sim 0.21''$; 23 March 2009). Methyl cyanide, like many nitriles and hydrocarbons on Titan, shows a strong latitudinal gradient. It is expected that these gradients will vary seasonally over the 30-year Titanian 'year'.

Small Solar System Bodies

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[2] Harvard-Smithsonian Center for Astrophysics, USA.

Understanding of the small bodies in the solar system is critical to our understanding of solar system formation and evolution. This class of bodies includes dwarf planets, moons, asteroids, comets, and Trans-Neptunian Objects (TNOs). Observations at longer wavelengths (submm to cm) are important because they allow us to probe into the subsurfaces of the bodies, something unique to those wavelengths. Such a probe yields information on composition and physical structure of that region of the subsurface. The smaller of these bodies have been difficult to observe in this wavelength range in the past due to the limited sensitivity of available telescopes, and even the larger bodies have been limited to unresolved observations. With the advent of ALMA and the upgrade to the VLA, it is now possible to make high-resolution, high-sensitivity observations at these wavelengths, allowing us to study them in detail in this heretofore unavailable range. We will present recent VLA observations of the Pluto/Charon system (see Figure 1 below) and several TNOs (Butler et al. 2011), discuss the prospects for observations of these bodies with ALMA (Moullet et al. 2011), present recent VLA observations of Near Earth Asteroid 2005 (YU55) (Busch et al. 2012), and discuss several other potential areas of growth in observations of small bodies with new or upcoming telescopes.

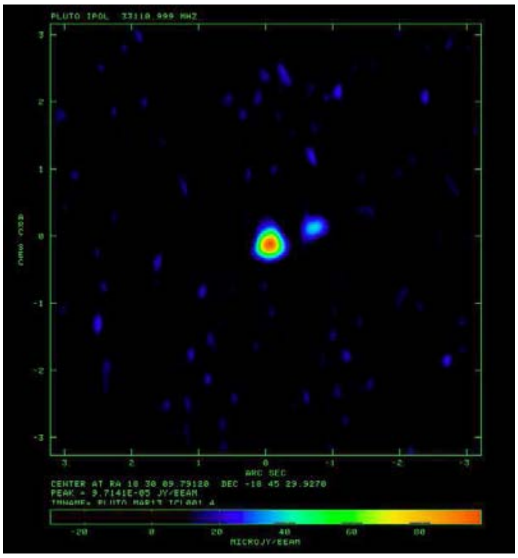

Figure 1: Image of Pluto and Charon at 1 cm wavelength from data obtained on March 13, 2010 with the Very Large Array. The separation of the two is obvious, and allows us to determine the brightness temperature of each of them individually.

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The Chemistry of Carbon and Oxygen-rich Evolved Stars

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[1] CAB. CSIC-INTA

Herschel's view on late stages of stellar evolution – New enigmas to be solved with ALMA

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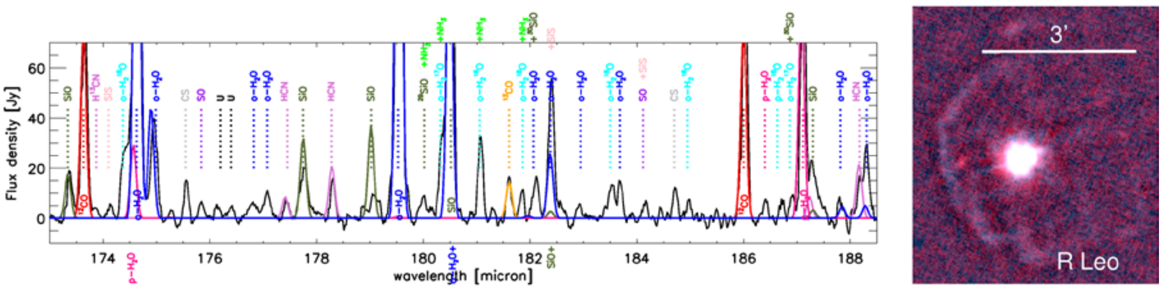
Mass loss is the dominating factor in the post-main sequence evolution of most stars but many aspects of the mass loss mechanism(s) are still not understood. The Herschel Space Observatory offers the astronomers some unique instruments (HIFI, PACS and SPIRE) to study circumstellar environments around evolved stars. We present the latest results obtained with Herschel in the field of low and intermediate mass evolved stars. The main focus of this talk will be on the chemistry occuring in the envelope of evolved oxygen-rich, carbon-rich and S-type Asymptotic Giant Branch (AGB) stars. Detailed analyses of the very rich infrared and sub-millimeter spectra show that various chemical processes, as shock-induced non-thermal equilibrium chemistry, ion-ion processes, photodissociation, etc. determine the chemical fractional abundances in the circumstellar environments around these evolved stars (see, e.g., left panel in the figure). In addition, recent images obtained with the PACS and SPIRE photometers show that the energetic encounter between the circumstellar material and ISM (see, e.g., right panel in the figure) is a very important player in establishing the exact chemical composition of the circumstellar material which is injected into the ISM. Using recent Herschel spectra and images, the different chemical processes will be discussed. I will show how the Herschel observations can answer some historical questions on these late stages of stellar evolution, but also add some new enigmas which potentially can be solved using ALMA.



Left panel: The continuum-subtracted PACS spectrum (black) of the red supergiant VY CMa between 173 and 188.5 μm (Royer et al. 2010). The main contributing molecules and isotopes are identified. Features not yet identified are indicated with a 'U'. The first modeling results are shown in different colors, corresponding to the different molecular species. *Right panel:* PACS 70 μm image of R Leo showing the interaction between the circumstellar and interstellar material.

Outflows in Late-type Stars

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The biggest challenge in the study of the final stage of low to intermediate mass (1–8 $M_{\odot}$) stars is the metamorphosis of a spherically symmetric asymptotic giant branch (AGB) star into a planetary nebula (PN) with highly asymmetric shape (such as bipolar or point symmetric shapes). During the AGB phase, stars loose their mass in slow ($V_{\rm exp}$∼15 km s^{-1}) spherical winds. Then, stars change their morphology and kinematics drastically in a subsequent very short (∼1000 yr) phase called proto-PN or post-AGB. In this transition phase, high-velocity (>100 km s^{-1}) outflows from the central stars (or star systems) are considered to be playing crucial roles in forming highly asymmetric structures. However, the origin of high-velocity outflows from evolved stars (PNe and proto-PNe) is still an open question. In this talk, I will review the recent observations of high-velocity outflows from evolved stars. I also compare the properties of high-velocity outflows from evolved stars with those of the outflows from young stellar objects.

From large scale surveys to ALMA observations of massive star forming regions.

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We have compiled a large molecular line data base of massive star forming regions in the southern Milky Way. These regions are confined within giant molecular, identified from our large scale CO survey, that trace the galactic spiral structure. The molecular gas radial distribution peaks midway between the Sun and the galactic center, corresponding in the IV quadrant to the location of the Norma Spiral arm. We study in some detail one of the foremost regions of massive star formation, G331.5, in the tangent region of Norma arm, using single dish millimeter continuum and line emission maps, as well as recent observations with ALMA.

Progress of ALMA Construction and Operations

T. HASEGAWA[1], S. IGUCHI[1], K. TATEMATSU[1], D. IONO[1] AND THE EAST ASIAN ALMA TEAM

[1] NAOJ Chile Observatory, National Astronomical Observatory of Japan.

The Atacama Large Millimeter/submillimeter Array (ALMA), an international astronomy facility, is a partnership of Europe, North America and East Asia in cooperation with the Republic of Chile. ALMA is approaching its end of construction and start of full operations expected in 2013, while its Early Science Operations since 2011 September is producing exciting results as we see in this conference. In this paper, we review the status of the ALMA construction and operations with an emphasis on the contribution from East Asia (EA), i.e., the Atacama Compact Array (ACA) and the receiver Bands 4, 8 and 10.

ACA has been designed and built to collect the spatially extended (i.e., low spatial frequency) components of the observed objects and to improve the fidelity of the resultant image. It consists of eleven 7-m antennas and four 12-m antennas. The commissioning observations of the ACA system on the galaxy M100 have demonstrated that it can indeed recover the spatially extended component of the object. The Band 4, 8 and 10 receiver cartridges are being delivered for installation at the Front End Integration Centers and at the ALMA Operations Support Facility.

ALMA: the Challenges of Construction and Operations

THIJS DE GRAAUW[1]

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The Atacama Large Millimeter/submillimeter Array (ALMA) is an international radio observatory under construction in the Atacama region of northern Chile. ALMA is a combination of two arrays of high-precision submm antennas: one made of fifty 12-meter antennas which can be arranged in configurations with diameters ranging from about 150 meters to 16 km. The other, the ALMA compact Array (ACA), consists of twelve 7-meter diameter antennas operating in closely-packed configurations of about 50m in diameter. In addition there will be four more 12-meter antennas to provide the zero-spacing information. The total collecting area will be 6600 m2. The antennas will be equipped with receivers covering most of the frequency range from 35 to 950 GHz.

The construction is progressing well and by now 50 (of the 66) antennas have been installed at the ALMA Observing Site (5000m). Operations started with Early Science observations. Cycle-0 observations are almost completed and the cycle-1 highest ranked proposals have been selected. These parallel activities show an interesting synergy between the activities for construction (hardware acceptance, site infrastructure works, AIV, CSV, software upgrades) and for operations (hardware and software maintenance, observing, data reduction,etc) but present at the same time a challenge to the joint observatory in transition phase from Construction-to-Operations.

As the first data show very interesting scientific results, that build up pressure for more observations, and construction needs to be completed with first priority (budget) an interesting balancing act is taking place.

Future Development of ALMA

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The Atacama Large Millimeter/submillimeter Array (ALMA) is already producing a growing number of impressive and scientifically compelling results during its first year of operation as the most powerful mm/submm interferometer in the world. In order to maintain ALMA as the state-of-the-art facility over the course of its projected life of 30+ years, continuing technical upgrades and development of new capabilities are essential. Here we present progress of the development studies/projects for the next 5 years with particular emphasis on our recent discussion and developments in the East Asian region. Specifically, we will focus our discussion on the recent progress and the scientific importance of band 1 (40 GHz). In addition, we will summarize our study of the development of the 1.3 - 1.5 THz band (Band 11) and briefly mention the status of the updated photonic LO system, and the development of the high-site artificial noise for the improvement of calibration accuracy which is led by the NAOJ. We also provide a status update of the other new receiver bands.

IRAM: Present and Future

PIERRE COX[1]

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In recent years, major changes were successfully done at the IRAM Plateau de Bure interferometer and the 30-meter telescope, in particular in the areas of receivers and back-ends. These enhancements increased in significant ways the sensitivity and the efficiency of both IRAM facilities. I will present results obtained on a variety of topics, emphasizing the studies of the high-redshift ($1 < z < 7.3$) sub-millimeter galaxies and quasars, that will illustrate the recent progress that has been made.

The talk will also describe the NOrthern Extended Millimeter Array (NOEMA), a project that will further enhance the IRAM interferometer in the ALMA era.

The Large Millimeter and Sub-millimeter Telescope Project, ”ALMA SPICA Synergy Telescope (ASTe)”

RYOHEI KAWABE[1], KOTARO KOHNO[2], SATOSHI YAMAMOTO[2], YOICHI TAMURA[2], & TAI OSHIMA[3]

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[2] The University of Tokyo
[3] Nobeyama Radio Observatory

Here we report on the new medium-scale plan in Japan to construct a 30 - 50 m class millimeter (mm) and sub-mm single dish telescope. The main observing frequency of the telescope is 70 to 400 GHz, which just covers main atmospheric windows in good observing sites at mm and sub-mm wavelengths such as the ALMA site. We are also aiming at observations at higher frequency up to 1 THz with the limited use of the antenna surface, e.g., under-illumination of the telescope. One of important science goals in this new telescope project is unveiling the large scale structure of the high-z universe and cosmic star formation history by spectroscopic surveys of high-z galaxies in CO and [CII] lines. With exploiting synergy with ALMA this telescope can contribute to the breadth of astronomy and astrophysics, e.g, astrochemistry, star formation in the galaxy and external galaxies, cosmology, and sub-mm VLBI.

The CCAT Project

GORDON J. STACEY[1]

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The CCAT telescope is a 25 m submillimeter telescope envisioned for a site near the summit of Cerra Chajnantor, in the Atacama desert in northern Chile. The large CCAT aperture with its high surface accuracy ($\sim 10\ \mu$m rms) and wide (1 deg) field of view, at the excellent Chajnantor site (less than 0.7 mm precipitable water, 50% of the time), together with the large format array cameras and spectrometers envisioned for the facility promise to deliver superb point source sensitivity and unrivaled mapping speed in the submillimeter telluric windows. I will discuss the characteristics of the CCAT facility including telescope and first light instrumentation, the primary science goals for the project, its current status and timeline, and finish with a discussion of the scientific synergies between CCAT and other contemporary faciliites. The CCAT project is a collaboration between Cornell University, Caltech, the University of Colorado, a consortium of Canadian Unversities (Dalhousie, McGill, McMaster, British Columbia, Calgary, Toronto, Waterloo, Western Ontario), the Universities of Cologne and Bonn, and Associated Universities, Incorporated, and the work is supported in part by the US National Science Foundation.

The LMT in the ALMA Era

MIN S. YUN[1]

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The Large Millimeter Telescope (LMT) is a 50-m diameter radio telescope designed to operate at the wavelength range between 1 and 4 mm. Taking advantage of its large collecting area (about 1/3 of ALMA) and high angular resolution (5” at 1.1mm), the main emphasis of the LMT instrumentation program is large format cameras with a wide wavelength coverage, exploiting the parameter space distinct from that of the ALMA: rapid large area mapping and ultra-wide spectral coverage. As a single aperture system, another distinct advantage of the LMT is that a unique instrument employing state-of-art technology can be deployed rapidly, unlike an interferometer. I will review the current suite of LMT instruments and those planned in the near future and the science goals these instruments aim to achieve during the next decade. I will also describe how the LMT will play an important complementary role to the ALMA in addressing a broad range of questions in different scientific areas.

The CCS 45 GHz Zeeman Project: Magnetic Field Measurements Towards Prestellar Cores

F. Nakamura[1], H. Ogawa[2], S. Kameno[3], K. Kimura[2], I. Mizuno[3], K. Tokuda[2], M. Takatsu[2], D. Iono[1], S. Takano[4], K. Dobashi[5], T. Matsumoto[6], N. Kuno[4], R. Kawabe[7], T. Onishi[2], M. Momose[8], H. Shinnaga[1], T. Tanaka[2], S. Yamamoto[9], H. Maezawa[2], and T. Hirota[1]

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[5] Tokyo Gakugei University.
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Stars are believed to form via gravitational collapse of dense cores. According to the standard scenario of star formation, the gravitational collapse is significantly influenced by magnetic fields. However, the role of magnetic fields in the gravitational collapse phase remains poorly understoond because of the difficulty of direct measurements of the core magnetic field strengths. Recent numerical simulations have revealed that the strong magnetic fields reduce the core angular momenta efficiently, resulting in the retardation or suppression of circumstellar disks (so-called magnetic braking catastrophe). Therefore, measuring the core magnetic field strengths is crucial to understand how star and planet formation takes place in the cource of the gravitational collapse of the dense cores. Until now, the magnetic field strengths in star forming regions have been measured mainly by the Zeeman obsevations using the HI and OH thermal and OH maser lines (see, however, the recent CN Zeeman observations towards massive star forming regions). Since these emission lines are generally not associated with the dense cores, it is difficult to estimate the core magnetic field strengths from these observations. To elucidate the role of magnetic fields in the gravitational collapse phase, we have started a project of the Zeeman measurements towards prestellar dense cores, using the CCS ($J_N = 4_3 - 3_2$) line by developing a new 45GHz band, dual polarization reciever for the NRO 45m telescope. The CCS molecule is known to be abundant in the prestellar cores in nearby star forming regions such as Taurus. In addition, CCS ($J_N = 4_3 - 3_2$) has a large magnetic dipole moment. Therefore, it is suitable to measure the core magnetic field strengths. In this presentation, we present the details of our CCS Zeeman project and the current status of the development of our new 45GHz band reciever.

The Next-Generation Infrared Astronomy Mission SPICA

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We present the overview and the current status of SPICA (Space Infrared Telescope for Cosmology and Astrophysics), which is a mission optimized for mid- and far-infrared astronomy with a cryogenically cooled 3.2 m telescope. SPICA has high spatial resolution and unprecedented sensitivity in the mid- and far-infrared, which will enable us to address a number of key problems in present-day astronomy, ranging from the star-formation history of the universe to the formation of planets. To reduce the mass of the whole mission, SPICA will be launched at ambient temperature and cooled down on orbit by mechanical coolers on board with an efficient radiative cooling system, a combination of which allows us to have a 3-m class cooled (6 K) telescope in space with moderate total weight (3.7t). SPICA is proposed as a Japanese-led mission together with extensive international collaboration. ESA's contribution to SPICA has been studied under the framework of the ESA Cosmic Vision. The consortium led by SRON is in charge of a key focal plane instrument SAFARI (SPICA Far-Infrared Instrument). Korea and Taiwan are also important partners for SPICA. US participation to SPICA is under discussion. The SPICA project is now in the "risk mitigation phase". The target launch year of SPICA is 2022.

The Event Horizon Telescope:
Observing Black Holes with Schwarzschild Radius Resolution

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It is now almost certain that at the center of our Milky Way Galaxy lies a super massive black hole - 4 million times more massive than our Sun. Because of its proximity to Earth, this object, known as Sagittarius A*, presents astronomers with the best opportunity in the Universe to spatially resolve and image a black hole Event Horizon. To do this requires using Very Long Baseline Interferometry (VLBI), the technique whereby radio telescopes around the world are linked together in a Global phased array. Very short wavelength VLBI observations have now confirmed structure on ∼4 Schwarzschild radius scales within SgrA*, and have revealed time variability in this source on the same spatial scales. For the much more massive (6 billion solar mass) black hole powering the relativistic jet in M87, similarly compact structures have been detected. I will describe the instrumentation efforts that enable these observations, discuss what current and future VLBI observations can tell us about these super-massive black holes, and describe plans for assembling a Global submm-VLBI Event Horizon Telescope that will incorporate ALMA as a beam formed single aperture.

The Greenland Telescope (GLT) Project

K. Asada[1], M. Inoue[2], S. Matsushita[3] and the GLT team[4,5,6,7]

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We report the latest overview of Greenland Telescope Project.

Imaging the shadow of the black hole is one of the ultimate goals for modern astrophysics. By imaging the super massive black holes (SMBHs) with its mass at the center of active galaxies, we can prove their existence directly, and determine their mass and spin parameters. Strong lensing effect is expected, which is crucial for testing general relativity in regime of strong gravitational field. In addition, imaging the vicinity of the black holes is important to investigate the launching mechanisms of the ultra-relativistic jets and the accretion process onto SMBHs. Even for the SMBHs, their expected angular sizes of the shadows are very small (40 - 50 micro arcseconds at largest). VLBI observations at submillimeter wavelength is one of the most effective methods to achieve sufficient angular resolution for imaging the shadow; VLBI observation at 345 GHz with 9,000 km baseline can provide an angular resolution of $\sim$ 20 micro arcseconds, about one order of magnitude better than current best angular resolution.

In order to realize the imaging of the shadow of SMBHs, one of our primary efforts is establishing a new submillimeter VLBI station in order to improve the angular resolution and image quality. In addition to VLBI usage, we plan to use the telescope in single dish mode as a pathfinder for THz astronomy. We plan to realize it by redeploying the ALMA-NA prototype antenna. Based on the atmospheric condition and geometrical configuration with other existing telescopes, we select the Summit Camp on Greenland as the possible new site for the prototype antenna.

We have already started a site-testing to measure the atmospheric transparency at submillimeter wavelength since August of 2011 for further studies of atmospheric condition at the site. In the meantime, we have started works on retrofitting the ALMA-NA prototype antenna to understand current status after its shut down and to adapt to the new environment.

Detailed on the project will be presented by M. Inoue in this conference.

(left) ALMA-NA prototype antenna at VLA site. (right) Working on the panel adjustment for photogrametry measurement.

P2

Sub-mm Singledish and Interferometric Observations of the Proto-cluster around 4C 23.56 at $z = 2.5$

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The proto-cluster around the radio galaxy 4C 23.56 at $z = 2.48$ is known as an overdense region of bright Hα emitters (HAEs) with their star formation rates (SFRs) $\sim$ a few 100 $M_\odot$ yr^{-1}, investigated by MOIRCS/SUBARU narrow band survey. This region should be the best site to study formation history of cluster massive galaxies at the early universe. We conducted AzTEC / ASTE deep 1.1 mm continuum survey toward this region. It covers $\sim$ 166 arcmin^2 wide area with 1σ = 0.6 - 0.9 mJy beam^{-1}. We robustly detect 35 of 1.1 mm sources with 3.5 - 16.7σ within the survey field. These sources have $L_{\rm FIR} \sim 3.0 \times 10^{12}$ - 2.0×10^{13} $L_\odot$ and SFRs $\sim$ 520 - 3380 $M_\odot$ yr^{-1} on some uncertainties of dust parameters and redshifts. We find a remarkable spacial coincidence between 1.1 mm sources and bright HAEs in 2×2 arcmin^2 or $\sim$ 3 Mpc scale. IRAC colors of HAEs are also consistent with that of SMGs at $z \sim 2.5$, implying that some 1.1 mm sources in this protocluster with SFR $\sim$ 1000 $M_\odot$ yr^{-1} are superposition of dusty HAEs with SFR $\sim$ a few 100 $M_\odot$ yr^{-1}. We successively conducted Plateau de Bure Interferometer (PdBI) follow up observation for dust continuum and CO(5-4) at 165 GHz. We detected 1.8 mm PdBI sources at the peak of each AzTEC sources. We also detected a CO(5-4) source which is identified with a HAE. The CO(5-4) emission shows a broad line shape (full width $\sim$ 1000 km s^{-1}), implying that this could be a multiple or merging system. The detected CO(5-4) luminosity corresponds to the molecular gas mass of 2.9×10^{10} $M_\odot$ assuming ULIRG-like CO-to-H_2 conversion factor. This results in a star formation efficiency (SFE) $\equiv L_{\rm IR} / L'_{\rm CO}$ of 144 $L_\odot$ (K km s^{-1} pc^2)$^{-1}$, suggesting that this HAE shows an intermediate SFE between quasars/SMGs ("starburst sequence") and gas-rich star-forming galaxies (i.e., "disk-mode sequence").

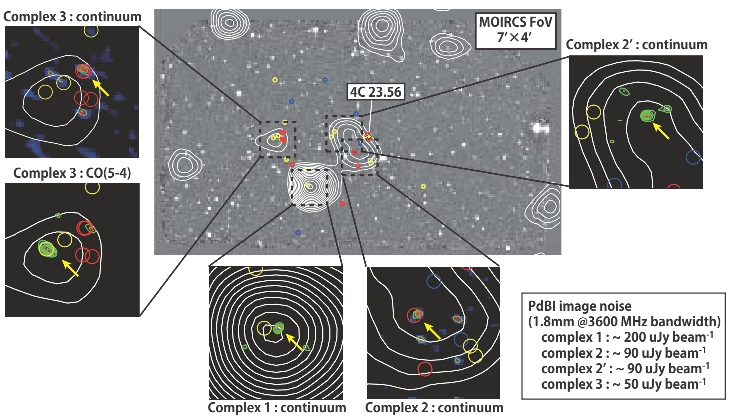

Figure 1: The spatial distributions of HAEs (circles with colors, red : SFR > 150 $M_\odot$ yr^{-1}, yellow ; 50 $M_\odot$ yr^{-1} < SFR < 150 $M_\odot$ yr^{-1}, blue ; 20 $M_\odot$ yr^{-1} < SFR < 50 $M_\odot$ yr^{-1}, respectively.), AzTEC 1.1 mm sources (white contours, 1σ steps from 3.5σ). Close up PdBI 1.8 mm continuum and CO(5-4) images (green contours, 1σ steps from 3σ.) for 4 complexes are also shown (Suzuki et al. 2012).

P3

Sub-millimetre galaxies in cosmological hydrodynamic simulations: Source number counts and the spatial clustering

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We use large cosmological Smoothed-Particle-Hydrodynamics simulations to study the formation and evolution of sub-millimetre galaxies (SMGs). In our previous work, we studied the statistical properties of ultra-violet selected star-forming galaxies at high redshifts. We populate the same cosmological simulations with SMGs by calculating the reprocess of stellar light by dust grains into far-infrared to millimetre wavebands in a self-consistent manner. We generate light-cone outputs to compare directly the statistical properties of the simulated SMGs with available observations. Our model reproduces the submm source number counts and the clustering amplitude. We show that bright SMGs with flux $S > 1$ mJy reside in halos with mass of $\sim 10^{13} M_{\odot}$ and have stellar masses greater than 10^{11} $\mathrm{M}_{\odot}$. The angular cross-correlation between the SMGs and Lyman-α emitters is significantly weaker than that between the SMGs and Lyman-break galaxies. The cross-correlation is also weaker than the auto-correlation of the SMGs. The redshift distribution of the SMGs shows a broad peak at $z \sim 2$, where Bright SMGs contribute significantly to the global cosmic star formation rate density. Our model predicts that there are hundreds of SMGs with $S > 0.1$ mJy at $z > 5$ per 1 square degree field. Such SMGs can be detected by ALMA.

P4

AzTEC/ASTE deep and wide submillimeter galaxy survey in the Subaru/XMM-Newton Deep Field: Identification of VLA, Spitzer and Herschel counterparts to 1100-μm-selected galaxies and redshifts

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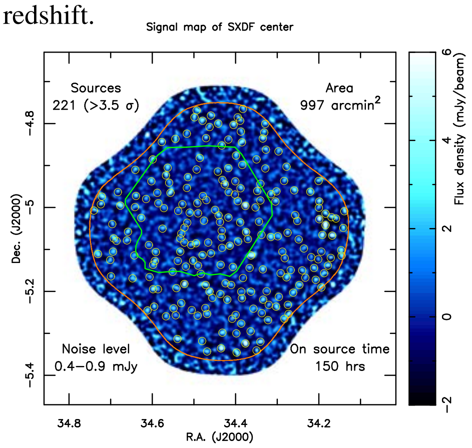
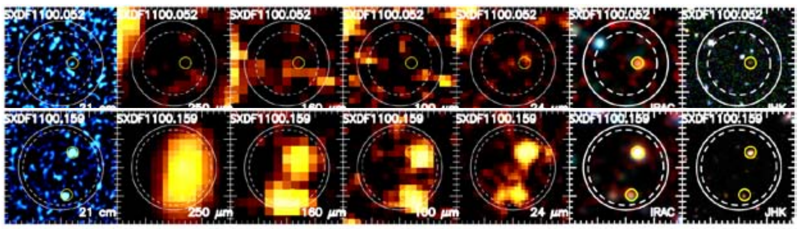
We present results of our AzTEC/ASTE submillimeter galaxies (SMGs) survey in the Subaru/XMM-Newton Deep Field (SXDF), and VLA (21 cm), *Spitzer* (3.6-8 μm and 24 μm) and *Herschel* (100 and 160 μm) counterpart identifications to 1100-μm-selected SMGs. We obtained a 1100-μm map of 997 arcmin^2 with the rms noise level of $\sim$0.5 mJy (1 σ). Our AzTEC map achieved new detections of 221 sources (S/N $\geq$ 3.5 σ). Deep *Herschel* PACS 100-μm and 160-μm images cover the whole of the AzTEC map, and 34 of 221 (= 15 %) and 54 of 221 (= 24 %)AzTEC sources have PACS 100-μm and 160-μm counterparts, respectively. We found VLA radio and/or MIPS 24-μm robust (with a significance of $\geq$ 95 %) counterparts to 102 of 221 the AzTEC SMGs. In addition to this, we have developed an improved identification method using IRAC data (3.6-8 μm) and their colors, in order to cover the AzTEC SMGs located at higher redshift such as $z > 3$, which is inaccessible with the existing VLA, MIPS and *Herschel* data alone. With this method, we have achieved another robust detections of 20 IRAC counterparts to AzTEC sources. 131 of 221 AzTEC sources have at least one robust counterparts, and 23 of 221 have more than two robust counterparts. Including tentative identifications (with a significance of $\geq$ 90 %), 164 of 221 (= 74 %) 1100-μm-selected SMGs have counterparts. We estimated photometric redshifts of the counterparts using deep near-, and med-infrared and optical data, providing z_{median} of 2.2. Among them, we found that there were some 1100-μm sources faint in multi-bands data suggesting the extremely high redshift.





(Left) AzTEC 1100-μm map of SXDF. The coverage of useful AzTEC/ASTE data is enclosed by orange solid line. The yellow circles show the positions of the detected AzTEC source. Green line shows the area covered by SCUBA in SHADES surveys (e.g., Coppin et al. 2006). (Right) Multi-wavelength images of AzTEC SMGs. Here, representative 2 targets are shown. From left to right: VLA, SPIRE, PACS, MIPS and IRAC images. Solid large white circles indicate the beam size of AzTEC/ASTE (30″) and dashed white circles show the 2σ position error on the AzTEC source. Solid yellow lines show the positions of the robust counterparts.

P5

Clustering Properties of 1.1 mm-selected Submillimetre Galaxies Uncovered by AzTEC Deep Surveys

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Millimetre/submillimetre-bright galaxy population (SMGs) are dusty starburst galaxies with star-formation rates (SFRs) of $\sim$1000 $M_\odot$ yr^{-1} at high redshifts ($z > 1$). While it is thought that SMGs may be the progenitors of massive elliptical galaxies in the present-day universe observed during their peak phase of stellar mass buildup, the evolutionary history of SMGs and their relationship to other galaxy populations at high-redshift and in the local universe are still uncertain.

We performed deep and wide-field surveys at 1.1 mm using AzTEC camera mounted on ASTE. We calculate the two-point angular autocorrelation functions in seven deep survey fields: AKARI Deep Field South (ADF-S), COSMOS, GOODS-S, Lockman Hole East, SSA 22, and SXDF. We detect evidence for clustering signals in all the fields. By averaging the results on the bright sources measured in the ADF-S, the SSA 22, and the SXDF fields, we derived a more significant correlation function of 1.1 mm sources. The correlation length for the combined data is estimated to be $r_0 = 13^{+4}_{-6}\ h^{-1}$ Mpc by assuming a Gaussian redshift distribution centered at $z = 2.5$ with a standard deviation of $\sigma_z = 0.5$. A comparison of the correlation length with a bias evolution model of dark halos suggests that dark halos hosting bright 1.1 mm sources evolve into galaxy clusters in the present-day universe. In this scenario, the 1.1 mm sources residing in the dark halos evolve into massive galaxies located in the clusters.

P6

Submillimeter Galaxies in the SSA22 Protocluster at z=3.1

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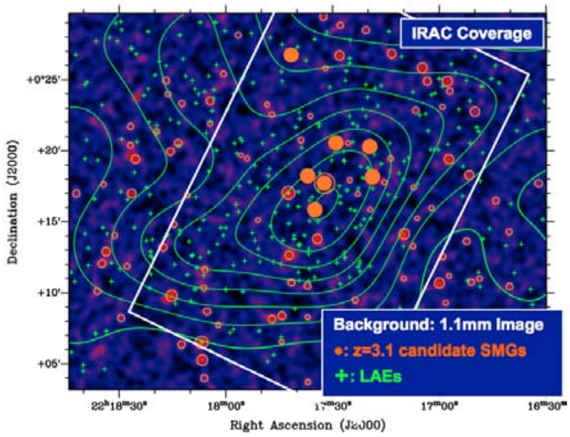
We present the results of counterpart identification of submillimeter galaxies (SMGs) detected in the SSA22 protocluster, which is traced by Lyα emitting galaxies (LAEs) at z = 3.1. 112 SMGs were uncovered in this field with a signal to noise ratio of $>$ 3.5 by a 1.1mm deep extragalactic survey with AzTEC camera mounted on the Atacama Submillimeter Telescope Experiment (ASTE) . We searched counterparts for these 1.1mm selected SMGs using the following three methods; radio(1.4GHz) , MIPS ch1(24μm), and IRAC color(3.6μm, 4.5μm, 5.8μm, and 8.0μm) diagnostics. As a result we identified 48 SMGs with at least one counterpart. Furthermore we extract 34 SMGs from those with counterpart and observed by IRAC 4 channels and derive their photometric redshifts with photometric data from optical to mid-infrared wavelength (at most 13 bands). Finally we identify seven SMGs as reliable candidates of z=3.1 protocluster member. Two point angular correlation function between LAEs and these SMGs shows that there are significant spatial correlation, which indicates SMGs are correlated with the large scale structure. These results indicate that high density regions at the high redshift universe are the site of SMG formation. This picture is consistent with predictions from the standard model of hierarichical structure formation. We also detect luminous X-ray emission ($Lx_{0.5-8.0\mathrm{keV}} \sim 10^{44}$ ergs s^{-1}) in three SMGs around the core of the protocluster, suggesting that these harbor luminous AGNs and are at the terminal stage of starbursts.



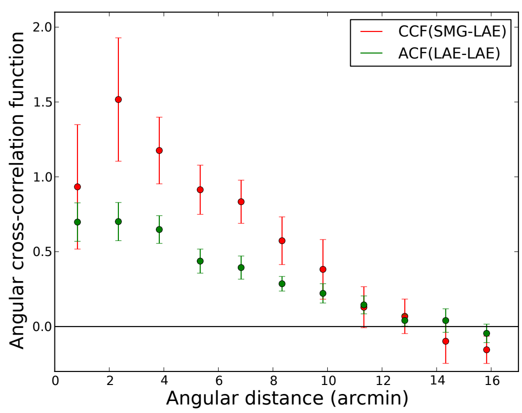


Figure1: (left) Sky distribution of SMGs. (right) Angular cross-correlation function between $z = 3.1$ candidate SMGs and LAEs.

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Tamura et al. 2009, Nature, 459, 61

P7

CO Observations of Distant Bright Galaxies at the 45m

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We present initial results from the CO survey toward high redshift galaxies using the Nobeyama 45m telescope. Using the new wide bandwidth spectrometer equipped with a two-beam SIS receiver, we have robust new detections of three high redshift (z = 1.6 − 3.4) submillimeter galaxies (SXDF 1100.001, SDP9, and SDP17), one tentative detection (SDSS J160705+533558), and one non-detection (COSMOS-AzTEC1). The galaxies observed during the commissioning phase are sources with known spectroscopic redshifts from previous optical or from wide-band submm spectroscopy. The derived molecular gas mass and line widths from Gaussian fits are $\sim 10^{11}$ $M_\odot$ and 430 − 530 km/s, which are consistent with previous CO observations of distant submm galaxies and quasars. The spectrometer that allows a maximum of 32 GHz instantaneous bandwidth will provide new science capabilities at the Nobeyama 45m telescope, allowing us to determine redshifts of bright submm selected galaxies without any prior redshift information.

P8

Tilted Cosmological Model With Barotropic Fluid Distribution

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Abstract. We investigated tilted Bianchi type I cosmological model for barotropic fluid ($p = \gamma\rho$), where p being isotropic pressure, ρ the matter density with $0 \le \gamma \le 1$. To determine the complete solution, we have assumed the relation between metric potential as A=BC. To get model in terms of cosmic time t, we have also assumed some special condition. The physical and geometrical aspects of both the model are discussed.

Keywords: Cosmology,Tilted cosmological model, Bianchi type-I universe, Barotropic fluid.
PACS numbers: 98.80.-k, 04.20.-q;

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P9

Molecular gas properties and star formation in interacting galaxies

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Galaxy encounters (e.g., collisions and mergers) play important roles for evolution of galaxies. Close galaxy-galaxy interactions greatly alter the distribution and kinematics of star and gas. During this phenomena, a significant enhancement of star formation is observed (Bushouse 1986). It is also known that the star formation activity follows evolution phases of interacting galaxies (hereafter IGs). While in IGs in early stage which show weak morphological disturbance star formation rate (SFR) is only a few times higher than field galaxies, SFR reaches to a few 10 times higher than field galaxies at late stage where two nuclei merge (Kennicutt et al. 1987). Especially, ultra luminous infrared galaxies (ULIRGs: $L_{\rm IR} > 10^{12} L_{\odot}$) most of which are thought to be in the late stage of the interaction (Clements et al. 1996) show bursts of star formation ($>$ 100 $M_{\odot}$ yr^{-1}).

It is, however, still open question how star formation is activated in IGs. Since molecular gas is a fuel of star formation, it is important to investigate how the interaction affects on molecular gas properties. Previous CO observations have been mainly focused on ULIRGs which are thought to have large amount of molecular gas. In fact, Young & Scoville (1991) showed that IR luminous galaxies have molecular gas of more than 10^{10} $M_{\odot}$. However, IGs in late stage like ULIRGs are not good for investigating the mechanism of active star formation in IGs because they already show burst of star formation. On the other hand, properties of molecular gas in IGs in earlier stage which will produce large amount of stars is not investigated well, since most CO observations are aimed at only the centre of galaxies.

We performed ^{12}CO(J = 1-0) OTF observations of four IGs in early and mid stage of interaction (Arp 84, VV 219, VV 254 and the Antennae Galaxies) using the 45-m telescope at Nobeyama Radio Observatory (Kaneko et al. submitted) and found the following facts.

The degree of the central concentration of molecular gas for IGs and isolated galaxies (data are taken from Nobeyama CO atlas, Kuno et al. 2007) are compared. In IGs the central concentration of molecular gas is lower than that in isolated galaxies. Taking account of results of the numerical simulations and the observations of galaxies in late stage, our results imply that central concentration of molecular gas decreases in the early stage at least once before falling into the nucleus.

We compared molecular gas fraction ($f_{\rm mol}$), the fraction of molecular gas to total gas (defined as the sum of molecular hydrogen gas and atomic hydrogen gas) in IGs with isolated galaxies, and found that IGs have higher molecular fraction. From the theoretical model (Elmegreen 1993) fitting to the observed $f_{\rm mol}$, we speculate that such high $f_{\rm mol}$ in IGs is due to external pressure and that the external pressure originates from the shocks induced by the interaction.

We assessed the relationship between molecular gas and star formation activity using star formation rate which is corrected dust extinction. No difference in Schmidt-Kennicutt relation is found between IGs in the early stage and isolated galaxies, although IGs have higher $f_{\rm mol}$ than isolated galaxies. On the other hand, IGs in the mid stage have higher SFE throughout the galaxies compared to those in the early stage.

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Derivation of the Mass of Super-Massive Black Hole

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We aim to establish a new method to derive the mass of Super Massive Black Hole (hereinafter SMBH; larger than $10^6 M_\odot$) in the center of the giant galaxies. The scientific importance of our study is:

- The determination of BH mass is fundamental to the field of black hole study; and
- This study suggests how SMBH and its host galaxy co-evolved, because the $M_{\mathrm{BH}} - \sigma$ relation, where the σ is the central velocity dispersion of its host galaxy can be updated.

Our NMA and RAINBOW observation in 2004 was not able to derive a velocity distribution map at 100-pc scale of the molecular gas surrounding the central black hole of a giant radio galaxy. With high performances of ALMA, however, we can obtain a high-quality image with an angular resolution of 0.3 arcsec which is equivalent to 100 pc of this object. In the future, ALMA can achieve higher resolution of 0.01 arcsec that corresponds to 3 pc at the redshift of this object. We show the simulation results of several rotational models from our position-velocity map, and will present how the model coincides with the observed map.

P11

Towards a Comprehensive Law of the Insterstellar Medium

S. Komugi[1,2], R. Miura[2], S. Onodera[3], N. Kuno[4], T. Tomoka[5] et al.

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Recent resolved observations of external galaxies have revealed that the relation between star formation rate and gas density breaks down at the scale of inidividual giant molecular clouds (GMCs). This shows that between individual GMCs, the interplay between the ISM and star formation is not expressible in terms of simple two-parameter laws like the Kennicutt-Schmidt law. Understanding the fundamental relation between various properties of GMCs and its environment is essential for gaining a comprehensive view of the ISM.

We have employed the Principal Component Analysis (PCA) approach to a catalogue of GMCs in the ultra-nearby galaxy M33 (Miura et al., submitted). By combining with the literature, we have compiled a large set of GMCs each with their size, line width, CO(J=3-2) luminosity, peak kinetic temperature, dust temperature, dust mass, K-band luminosity and star formation rate, along with the metallicity for a subset of sources. The GMCs are grouped by their type, a discrete measure of their evolutionary state. The PCA allows the derivation of the most fundamental relations between these parameters, while constructing a new set of orthogonal axes which describe the ISM better than the original parameters.

The most important relations derived from the PCA are found to include the equivalent of the Kennicutt-Schmidt (KS) relation and Larson's relation, as well as some other empirical relations which were previously unknown. In particular the KS relation includes parameters other than the CO luminosity and star formation rate, naturally revealing a new multi-parameter star formation law. Since these relations are constructed based on individual GMCs, the new relations are able to bridge between resolved and unresolved galaxies via spatial averaging. The PCA is also able to give actual values on the degree of importance of various physical parameters in these series of empirical laws.

I will review the process of the PCA, the results, and its future applications in the field of numerical simulations and interpretation of distant galaxies.

P12

The Star Formation Law in Similar-Age Regions; Case Study of the Early-Phase Interacting Galaxy Taffy I

S. Komugi[1,2], K. Tateuchi[3], K. Motohara[3], T. Takagi[4], D. Iono[2,5], H. Kaneko[6], J. Ueda[5,7], T. R. Saitoh[8] and TAO/ANIR project team.

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In order to test a recent hypothesis that the dispersion in the Schmidt-Kennicutt law arises from variations in the evolutionary stage of star forming molecular clouds, we compared molecular gas and recent star formation in an early-phase merger galaxy pair, Taffy I (UGC 12915/UGC 12914, VV 254) which went through a direct collision 20 Myr ago and whose star forming regions are expected to have similar ages. Narrow-band Paα image is obtained using the ANIR near- infrared camera on the mini-TAO 1m telescope. The image enables us to derive accurate star formation rates within the galaxy directly. The total star formation rate, 22.2 $\mathrm{M}_{\odot}$ yr^{-1}, was found to be much higher than previous estimates. Ages of individual star forming blobs estimated from equivalent widths indicate that most star forming regions are 7 Myr old, except for a giant HII region at the bridge which is much younger. Comparison between star formation rates and molecular gas masses for the regions with the same age exhibits a surprisingly tight correlation, a slope of unity, and star formation efficiencies comparable to those of starburst galaxies. These results suggest that Taffy I has just evolved into a starburst system after the collision, and the star forming sites are at a similar stage in their evolution from natal molecular clouds except for the bridge region. The tight Schmidt-Kennicutt law supports the scenario that dispersion in the star formation law is in large part due to differences in evolutionary stage of star forming regions.

P13

Microarcsecond structures of FSRQs 3C 279 and NRAO 530 revealed by Event Horizon Telescope observations

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VLBI observations at short millimeter wavelengths ($\leq$ 1.3 mm, $\geq$ 230 GHz) achieve extremely high-spatial resolution of tens of μas and enable direct studies on the nearby super massive black holes and the roots of relativistic jets in active galactic nuclei. Recently, the application of new technical developments and the appearance of new suitable antennas have established the technical feasibility of VLBI at such short mm-wavelengths with the Event Horizon Telescope (EHT; Doeleman et al. 2008, Fish et al. 2011). Here, we present the latest results of 1.3 mm VLBI observations in 2011 with the EHT towards the two well-known flat-spectrum ratio quasars NRAO 530 and 3C 279.

3C 279 (z=0.536) is one of the most intensively studied blazars because of its remarkably strong variability in broad-band from radio to Gamma-ray and high optical polarization. On the other hand, NRAO 530 (z=0.902) is also known to be strongly variable at various wavelengths from radio to Gamma-ray. After the launch of Fermi, it underwent a GeV gamma-ray flare at the end of October, 2010 (D'Ammando & Vandenbroucke 2010). The extremely high resolution of the EHT enables us to explore inner-jet structures on a sub-pc scale that could give a clue for interpreting their broad-band variability.

We carried out 1.3 mm VLBI observations of 3C 279 and NRAO530 with the EHT in April 2011, 6 months after the above Gamma-ray flare on NRAO 530. In these observations, the 1.3 mm VLBI array consisted of three stations on Mauna Kea (SMA, JCMT and CSO) in Hawaii, the CARMA array in California and the AROSMT in Arizona, enabling us to sample visibilities from few kλ to $\sim$ 3.5 Gλ. Strong fringe detections were made on both sources on all baselines. Furthermore, we robustly detected non-zero closure phases for both sources, indicating the presence of asymmetric compact structure. This is the second detection of closure phases in 1.3 mm VLBI observations.

In this talk, we report the first 1.3 mm VLBI models of 3C 279 and NRAO 530 using visibility amplitudes and closure phases. Then, we discuss relations between the models and multi-wavelength properties of these two sources. Finally, based on current EHT results, we discuss future possibilities for collaboration between the EHT including ASTE and the East Asia mm-VLBI network including VERA+KVN and the NRO 45m telescope.

References:

D'Ammando, F., & Vandenbroucke, J. 2010, The Astronomer's Telegram, 3002, 1
Doeleman, S.S., Weintroub, J., Rogers, A.E.E., et al. 2008, Nature, 455, 78
Fish, V. L., Doeleman, S.S., Beaudoin, C., et al. 2011, ApJL, 727, L36

P14

Detection of CO($J = 1 - 0$) Emission from Barred Spiral Galaxies at $z \sim 0.1$.

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Bars in disk galaxies are thought to influence the evolution of disk galaxies through redistributing angular momentum among the galaxy components, such as stars, gas and dark matter, and transferring gas to the central kiloparsec regions. Previous studies have revealed that almost 70 % of disk galaxies in the local universe have bars in their inner regions. Furthermore Sheth et al. (2008, ApJ, 390, 426) showed that the fraction of the barred spiral galaxies among disk galaxies increases from $z \sim 0.8$ to date. It is important to study molecular gas properties of the barred spiral galaxies at intermediate redshift ($z \sim 0.1 - 1.0$) for studying their evolution, while there has been no observation toward the barred spiral galaxies in this redshift range.

We will present the results of CO ($J = 1 - 0$) observations toward nine barred spiral galaxies at $z = 0.08 - 0.25$ using the 45 m telescope at Nobeyama Radio Observatory. This survey is the first one specialized for barred spiral galaxies in this redshift range. We successfully detected CO emission from six galaxies out of nine, whose CO luminosity ($L'_{\rm CO}$) ranges $(1.09 - 10.8) \times 10^9$ K km s^{-1} pc^2. These are the infrared (IR) dimmest galaxies that have ever been detected in CO at $z \sim 0.1$ to date. They follow the $L'_{\rm CO} - L_{\rm IR}$ relation among local spiral galaxies, Luminous Infrared Galaxies (LIRGs), Ultra-Luminous Infrared Galaxies (ULIRGs) and Sub-millimeter Galaxies (SMGs) as shown in figure a (from Matsui et al. 2012, PASJ, 64, 55). Their $L'_{\rm CO}$ and $L_{\rm IR}$ are higher than that of local spiral galaxies which have been detected in CO so far, and $L_{\rm IR}/L'_{\rm CO}$, which is a measure of star formation efficiency, is comparable to or slightly higher than that of local ones (see figure b). This result suggests that these galaxies are forming stars more actively than local spirals galaxies simply because they have more molecular gas as the fuel for star formation.

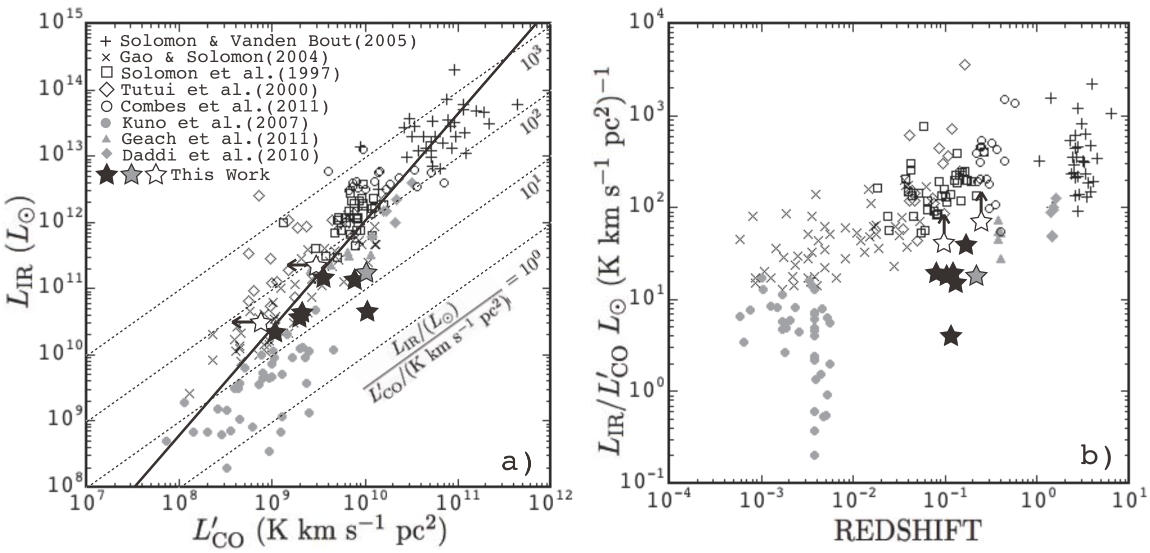

Figure 1: The black, gray and white stars in the plots represent the CO-detected galaxies (S/N>5), the marginally CO-detected galaxies (S/N∼4.4) and not CO-detected galaxies (S/N<3) in this work.

P15

Structured Molecular Gas Reveals Galactic Spiral Arms

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We have carried out survey observations toward the disk of the Milky Way (MW) in the ^{12}CO and ^{13}CO $J = 1$–0 lines using the Nobeyama Radio Observatory 45 m telescope. The line of sight at $l \approx 38°$ samples the gas in both the Sgr arm and the inter-arm regions. The data reveal how the spatial structures in molecular gas vary across the spiral arms. We classify the molecular gas into two distinct components based on its appearance: the bright and compact (*structured*) component and the fainter and diffuse (i.e., spatially extended) component. The former is predominantly seen at the spiral arm velocities, while the latter dominates at the inter-arm velocities and is also found at the spiral arm velocities. We introduce the *brightness distribution function* (BDF) and the *brightness distribution index* (BDI, which indicates the dominance of the bright and compact component) in order to quantify the spatial structure of the gas. The radial velocities of BDI peaks coincide with those of high ^{12}CO $J = 3$–$2/J = 1$–0 ratio (i.e., warm/dense gas) and H II regions.

We then explore the development of structures in molecular gas in a much wider area of the MW disk, by applying the analysis of the BDF and BDI to the archival data from the Boston University–Five College Radio Astronomy Observatory ^{13}CO $J = 1$–0 Galactic Ring Survey. The structured molecular gas traced by higher BDI is located continuously along the spiral arms in the MW in the longitude–velocity diagram. This clearly indicates that molecular gas changes its structure as it flows through the spiral arms. Although the high-BDI gas generally coincides with H II regions, there is also some high-BDI gas with no/little signature of on-going star formation. These results support the possible evolutionary sequence; unstructured, diffuse gas transforms itself into structured state on encounter with the spiral arms, then star formation follows and eventually the gas returns to the unstructured state as it leaves the arms.

P16

Disruption of Giant Molecular Associations by Shear Motion in the Spiral Galaxy M51

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Understanding of the evolution of Giant Molecular Associations (GMAs) is important to improve our knowledge about massive star formation and galaxy evolution. We have investigated the dynamics of the molecular gas and the evolution of GMAs in the spiral galaxy M51 with the NRO 45-m telescope. The velocity components of the molecular gas perpendicular and parallel to the spiral arms were derived at each spiral phase from the distribution of the line-of-sight velocity of the CO gas. In addition, the shear motion in the galactic disk was determined from the velocity vectors at each spiral phase. It was revealed that the distributions of the shear strength and of GMAs are anti-correlation each other. This result suggests that the GMAs are destructed into GMCs by the strong shear, although surviving in the weak shear.

P17

Kennicutt-Schmidt Law From Nearby Galactic Center to the Disk: On the Aspect of ^{13}CO

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The star formation of galaxy is commonly expressed as Kennicutt-Schmidt Law (K-S Law), which relates the surface densities of molecular gas ($\Sigma_{\mathrm{H_2}}$) and star formation rate (Σ_{SFR}) with the form of $\Sigma_{\mathrm{SFR}} = A{\Sigma_{\mathrm{H_2}}}^N$, where $N \approx 1.4$. Even though the physical processes leading to the K-S Law are not fully clear yet, the K-S Law has implied that the amount of molecular gas positively correlates with SFR. ^{12}CO has been widely used as a tracer of molecular gas owing to its high abundance and intensity. However, ^{12}CO suffers from the nature of optically thick. Thus it is worth seeking for an optically thin line, such as ^{13}CO and re-examining the K-S Law by determining the true mass of molecular gas. Since the sensitivity of NRO 45 m telescope has been improved, we made ^{12}CO (1–0) and ^{13}CO (1–0) spectral observation toward nearby spiral galaxy NGC 628 in 2012. In the preliminary results of NGC 628, surprisingly, the $\Sigma_{\mathrm{H_2}}$ derived from ^{13}CO positively relate to the Σ_{SFR}, while the correlation seems to be breakdown in ^{12}CO (Fig. 1). We then carried out the similar analysis with published data of the 45 m telescope of IC 342 (Hirota et al. 2010). For IC 342, the slope of K-S law appears to be changing among the center, bar, arm and inter arm regions of IC 342 (Fig. 2). Moreover, in both galaxies ^{12}CO overestimates the true mass of molecular gas. In poster, we discuss the possible reasons of the striking difference between the results of ^{12}CO and ^{13}CO for NGC 628 and the likely factors affecting the slope of the K-S plot in different galactic features of IC 342.

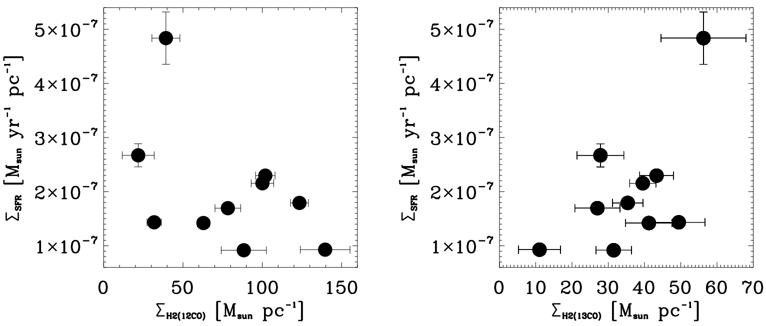

Figure 1: Preliminary results of NGC 628. The left and right panels show the K-S plot with molecular gas mass derived by ^{12}CO and ^{13}CO, respectively.

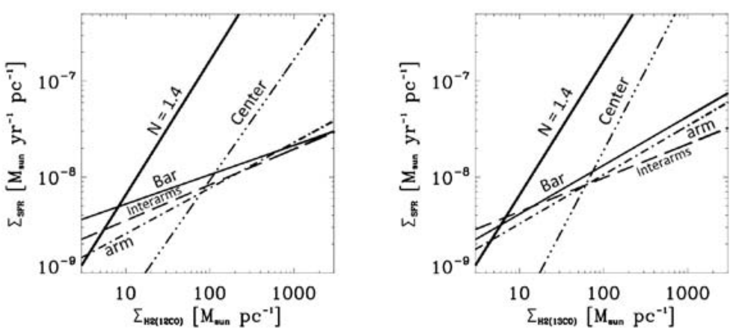

Figure 2: The K-S plot of IC 342. Here only shows the results of fitting, the complete results including the fitting of K-S Law and the observing data are shown in poster in color version. The left and right panels show the K-S plot with molecular gas content derived by ^{12}CO and ^{13}CO, respectively. The K-S plot with slope 1.4 is indicated to compare (with arbitrary constant A of K-S Law).

References:

Hirota, A., Kuno, N. et al. 2010, PASJ, 62, 1261

P18

Feedback Mechanisms of Starbursts and AGNs through Molecular Outflows

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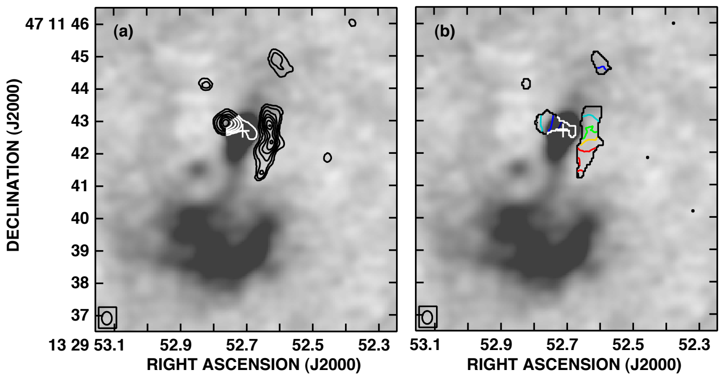
I report our interferometric observations of molecular outflows from nearby starburst and Seyfert galaxies.

Molecular outflows and superbubbles from edge-on starburst galaxies we detected are large, around a few hundred pc to a few kilo-pc scales, but diffuse and weak. Since these features are located away from the galactic disks with systematic motion, it is rather easy to distinguish from the galactic (non-outflowing) disk gas. Since X-ray outflows are located inside of the molecular outflows or superbubbles with comparable or larger energies and pressures than those of molecular outflows, these indicate that the molecular outflows and superbubbles are pushed out by the X-ray outflows (Tsai et al. 2009, 2012). In M82, since the current starburst regions are located at the inner edge of the superbubble, we suggest that the expansion of the superbubble caused by the past starburst triggered the current starburst (Matsushita et al. 2000, 2005).

Molecular outflows from nearby Seyfert galaxies are much smaller, around ten-pc-scale, so high spatial resolution imaging is essential. Molecular outflows in Seyfert galaxies are located and moving along the AGN jets; in case of M51, molecular gas along radio jets has similar kinematics as ionized gas along the jets, suggesting that the molecular outflows are entrained by the AGN jets (Matsushita et al. 2007; see figures below). On the other hand, molecular gas near an AGN without jet does not show such feature, suggesting that the existence of the AGN jets affects the molecular gas structures around AGNs.

In both starburst and Seyfert galaxies, the strong activities affect the existing molecular gas that can be the fuel for the activities themselves. We may be observing the feedback mechanisms in starburst galaxies and AGNs.



Central $\sim 10''$ images of M51 CO(2-1) (a) integrated intensity and (b) intensity-weighted velocity field in contours. Greyscale image is the VLA 6 cm continuum emission (Crane & van der Hulst 1992). Cross indicates the location of the Seyfert 2 nucleus. Molecular gas at the western side of the nucleus is elongated along the radio jets with smooth velocity gradient (Matsushita et al. 2007).

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Crane & van der Hulst 1992, AJ, 103, 1146
Matsushita, S., et al. 2000, ApJ, 545, L107
Matsushita, S., et al. 2005, ApJ, 618, 712
Matsushita, S., Muller, S., & Lim, J., 2007, A&A, 468, L49
Tsai, A.-L., et al. 2009, PASJ, 61, 237
Tsai, A.-L., et al. 2012, ApJ, 752, 38

P19

Boiling Molecular Cloud in the Central Molecular Zone

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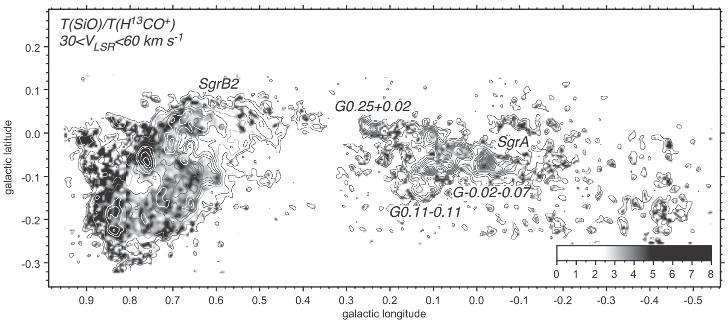
The Central Molecular Zone (CMZ) (Morris and Serabyn, 1993) is a molecular cloud complex in the Galactic center region, which is the nearest central region of a spiral galaxy. This is the counterpart of a central molecular cloud condensation often observed in nearby spiral galaxies and containing molecular gas of several 10^7 $M_\odot$ (e.g Tsuboi et al. 1999). We present results of a high-resolution wide-field mapping observation of the CMZ in SiO $v = 0, J = 2-1$ and $H^{13}CO^+$ $J = 1-0$ emission lines using the 25-beam receiver of 100 GHz band equipped in the Nobeyama Radio Observatory 45-m telescope (also see Tsuboi et al, 2011). The observations were performed during a survey program of the CMZ in order to explore molecular gas affected by shock in the regions and depict the high density molecular gas mass distribution.

There is a significant difference between the Sgr A and Sgr B2 complexes in $R = T(\mathrm{SiO})/T(\mathrm{H^{13}CO^+})$. The Sgr B2 molecular cloud complex has several expanding shell-like structures. They have high ratio ($R > 8$) and very wide velocity width ($\Delta V > 50$ km s^{-1}). On the other hand, there is no such high ratio area in the Sgr A complex although several expanding molecular shells are identified. Molecular cloud clumps are found using CLUMPFIND in the $H^{13}CO^+$ data cube and the clump mass functions (CMFs) are derived. The CMFs of the Sgr A and Sgr B2 complexes can be described by a similar power law (the power index is $\alpha \simeq -2$; $dN/dM \propto M^\alpha$) up to $M_{clump} < 1 \times 10^5$ $M_\odot$. In the higher mass range, although the CMF of the Sgr A complex still has the same power law, that of the Sgr B2 complex steepens rapidly. The origin of these expanding shells containing vast shocked molecular gas is still open. However, the properties of the shells may be a key information to understand active star formation in the central regions of galaxies.



The brightness temperature map (gray scale) of $T(\mathrm{SiO})/T(\mathrm{H^{13}CO^+})$ in the CMZ. The velocity range is $30 < V_{\mathrm{LSR}} < 60$ km s^{-1}. The contours shows the distribution of SiO emission line. The Sgr B2 molecular cloud complex contains several shell-like structures with very high ratio (> 8).

References:

Morris, M., Serabyn, E, 1996, ARAA, 34, 645
Tsuboi, M. et al. 1999, ApJS, 120,1
Tsuboi, M. et al. 2011, PASJ, 63, 763

P20

ALMA Observations of the IR-bright Merger VV114

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The importance of galaxy mergers in the context of galaxy formation and evolution have been clearly demonstrated in various numerical simulations. The violent merger event not only results in large scale morphological transformation and mass accumulation, but it also triggers gas compression, turbulence, and gas inflow to the galactic center region. While our theoretical understanding has advanced significantly over the past few decades, observational studies have been hampered by the limit in sensitivity and resolution of the existing instruments.

Here, we present preliminary ^{12}CO(1-0), ^{13}CO(1-0), ^{12}CO(3-2), ^{13}C0(3-2), HCO^{+}(4-3) and HCN(4-3) maps of an IR-bright late stage merger VV114 obtained during cycle 0 of ALMA. This set of lines allow to probe the molecular gas distribution from the bulk of the gas to the denser and warmer components. The new data is more than an order of magnitude deeper than the past images, revealing detailed structure and tidal tails that were unseen before. The kinematical signature obtained from ^{12}CO(1-0) [beam size = 2.0” 1.3”] will be compared with the dense gas tracers in HCO and HCN lines, and will also be compared with star formation tracers and ages obtained through optical images.

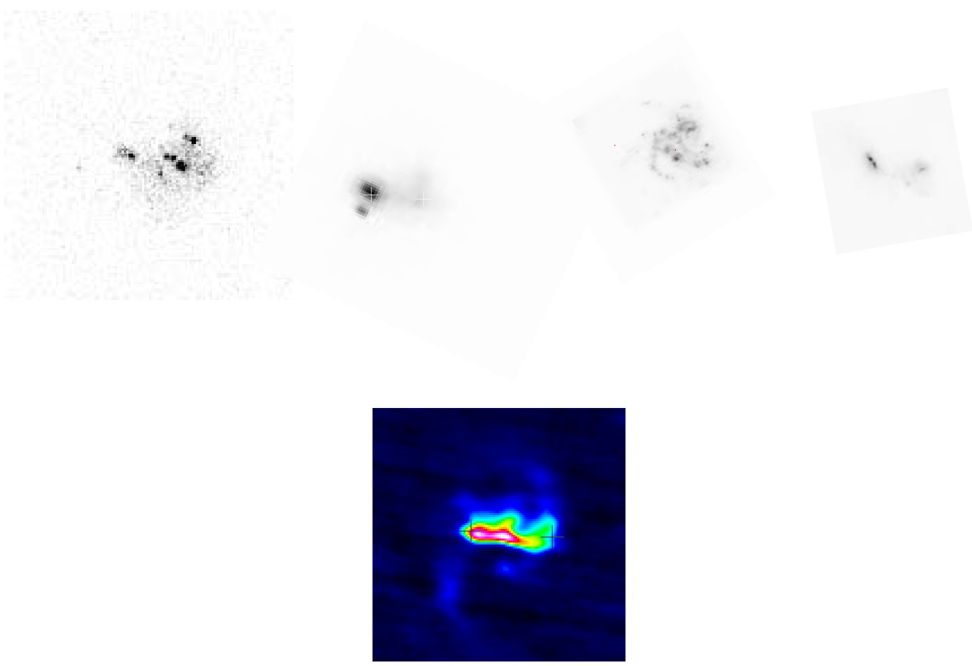

Figure 1: All annotations show the nuclei of each galaxies VV114E and VV114W. (Top Left) Chandra image finds extended X-ray emission. (Top Center-left) Spitzer/IRAC image. (Top Center-right) HST/STIS far UV image. (Top Right) HST/NICMOS image. (Bottom) ALMA ^{12}CO(1-0) integrated intensity image.

P21

Interstellar dust properties of M51 from AKARI mid-infrared images

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Using mid-infrared (MIR) images of four photometric bands of the Infrared Camera (IRC) onboard the AKARI satellite, S7 (7 μm), S11 (11 μm), L15 (15 μm), and L24 (24 μm), we investigate the interstellar dust properties of the nearby pair of galaxies M51 with respect to its spiral arm structure. The arm region is defined by applying the wavelet analysis to a 3 μm image, which traces the stellar mass distribution. We measure a flux contrast between the defined arm and interarm regions for each band. The contrast is lowest (~ 2.4) in the S11 image, which is interpreted as this band best represents the total dust distribution including colder components, while the L24 image with the highest contrast (~ 3.1) traces warmer dust heated by star forming activities.

The surface brightness ratio between the bands, i.e. color, is measured over the disk of the main galaxy, M51a, at 300 pc resolution. We find that the distribution of S7/S11 is smooth and well traces the global spiral arm pattern while L15/S11 and L24/S11 peak at individual HII regions. Among many PAH band features in MIR, it is known that ionized PAHs are dominant carriers of the 7μm feature while ionized and neutral PAHs both contribute to the 11μm feature. The S7/S11 result thus indicates that the ionization state of PAHs is related to the spiral structure. However, the driving mechanism is not yet clear from currently available data sets. Comparison with observational data and dust models also supports the importance of the variation in the PAH ionization state within the M51a disk. Furthermore, existence of very small grains with high temperatures around bright HII regions and a higher PAH fraction to the total dust mass are suggested. Relationships between these dust properties and molecular and atomic gas distributions obtained from radio observations are also investigated.

P22

Jet Kinematics and Absorbing Matter in the Quasar 1413+135

Minju Lee, Haruka Hiwaki, Seiji Kameno

We study the kinematics of jet of the radio-loud quasar 1413+135 based on the archival data from MOJAVE VLBA monitoring at $\lambda = 2$ cm. The quasar 1413+135 is known to have superluminal jets which have a knot that runs at the speed of $\beta_{\rm app} = 1.8 \pm 0.2$ at maximum. We developed a simple analyzing tool for measuring the speed of jets. We found one jet component at apparent speed of $\beta_{\rm app} = 1.29 \pm 0.13$ which was consistent with previous researches. The apparent speed yields the viewing angle and the minimum speed of $\theta \sim 38^\circ$ and $\beta_{\rm min} = 0.79 \pm 0.12$, respectively. We also found the flux density variation which was possibly caused by surrounding materials in the vicinity of the nucleus. We consider that the flux density of the knot has increased as it escapes from the surrounding absorber.

P23

ALMA cycle-0 observation of the Sombrero galaxy (M104)

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The Sombrero galaxy is quite unique because of the nearest (9.3 Mpc) super massive black hole with $10^9\ M_\odot$ as an extreme sub-Eddington and jet-suppressed accretion system. In the ALMA cycle-0, we have carried out point source photometry toward the Sombrero galaxy at (quasi-simulteneous) fifteen sideband frequencies in the band-3, 6, 7 and 9 to obtain continuum spectra for understanding of accretion and outflow phenomena in about 10 Schwarzschild radius or less. This is the most direct and promising approach to the vicinity of the event horizon, in advance of a future submm VLBI. We present a progress report of our study.

P24

Search for Extragalactic H_2O Maser Toward Active Galaxies

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The results of single-dish surveys for 22 GHz H_2O maser emission toward the nuclei of active galaxies using the Nobeyama 45-m telescope and Effelsberg 100-m telescope will be reported. The primary aim is a search for the H_2O maser in relatively nearby (v_{sys} < 30,000 km/s) narrow-line Seyfert 1 galaxies (NLS1s), which are known to have a smaller black hole mass than expected from M_{BH}-M_{Bulge} relations despite their luminosities being comparable to those of broad-line Seyfert 1 galaxies. The surveys were conducted with expectation that follow-up VLBI observation of the H_2O maser in NLS1 could prove a molecular gas disk and high mass accretion rate onto central engine in this particular type of galaxy. The observed galaxies were selected from radio-bright NLS1s detected in the NVSS survey at either 1.4 GHz or 5 GHz. In these surveys, no new H_2O maser has been detected at luminosity upper limit of $< 5\ L_{\odot}$, confirming that strong H_2O masers are not associated with the nuclei of NLS1s. The nature of the known H_2O maser in NLS1s will be discussed by using, for example, the correlation between radio and H_2O maser luminosity.

P25

^{12}CO(J=1-0) Survey with NRO 45 m of GOALS Luminous Infrared Galaxies: Star Formation Efficiency against Galactic Merger and AGN Activity

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[3] National Astronomical Observatory of Japan
[4] National Optical Astronomy Observatory
[5] Spitzer Science Center, California Institute of Technology
[6] Institute of Astronomy, The University of Tokyo

We present the results of the survey of ^{12}CO(J=1-0) from nearby luminous infrared galaxies (LIRGs: $L_{\rm IR} > 10^{11}\,L_{\odot}$) with Nobeyama 45 m telescope. This survey has been conducted to investigate star formation activities in LIRGs, providing their molecular gas mass. The star formation efficiency (SFE) on average is comparable to typical ones of normal galaxies and giant molecular clouds in Milky Way. The SFE has no correlations with the galactic merger stages and the active galactic nuclei (AGN) activity.

The nuclear activities in the nearby LIRGs are various such as violent star-forming or AGN. The morphology of the nearby LIRGs range from isolated galaxies or the early stage to the final stage of the galaxy-galaxy merger/interaction, which can trigger starburst events. Understanding the star formation and the evolution of local LIRGs need to investigate how the energy sources and the merger stages relate to the IR emission or the star formation. The Great Observatory All-sky LIRG survey (GOALS) is a project to reveal the true character of nearby LIRGs by combining multi-wavelength imaging and spectroscopic data. The samples of this survey are an unbiased subset of LIRGs in the GOALS project.

We obtained the molecular gas mass $M_{\rm H_2}$ in nearby 39 LIRGs by using the ^{12}CO(J=1-0) emission line. We found that these nearby LIRGs have $M_{\rm H_2}$ of $2.9\times10^9 - 9.9\times10^{10}\,M_{\odot}$. The CO luminosity have a correlation with the IR luminosity $L_{\rm IR}$, scaled to a 15$''$ beam of the CO observation. The average SFE inferred from $L_{\rm IR}/M_{\rm H_2}$ is $0.62 \pm 0.44\,{\rm Gyr}^{-1}$, which is about 10 times lower than the nearby ULIRGs' typical SFE and is comparable to the SFE of local normal galaxies and giant molecular clouds in Milky Way. $L_{\rm IR}/M_{\rm H_2}$ is compared with the merger stages classified by their morphologies of the optical images (Figure A), and with 6.2 μm polycyclic aromatic hydrocarbon equivalent width (PAH EQW), which indicates AGN contribution to Mid-IR emission (Figure B). There are no correlation between both. The SFE of nearby LIRGs may be independent on the presence of AGN and the phases of mergers, and the stars are being formed with a roughly the same and moderate efficiency; although some uncertainties from the beam aperture, the merger classification or a CO-H_2 conversion factor are remained.

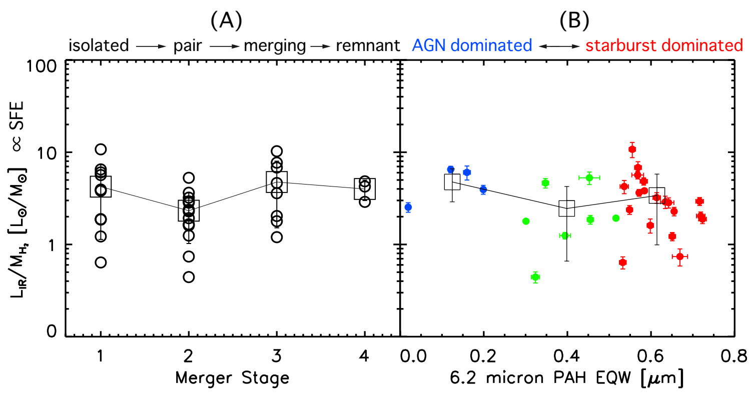

Figure: (A) The star formation efficiency (SFE) of nearby LIRGs at each merger stages. (B) The SFE vs. 6.2 μm PAH EQW which is an indicator of AGN activities on Mid-IR.

P26

Nobeyama 45 m Telescope Legacy Project: Line Survey of Galaxies

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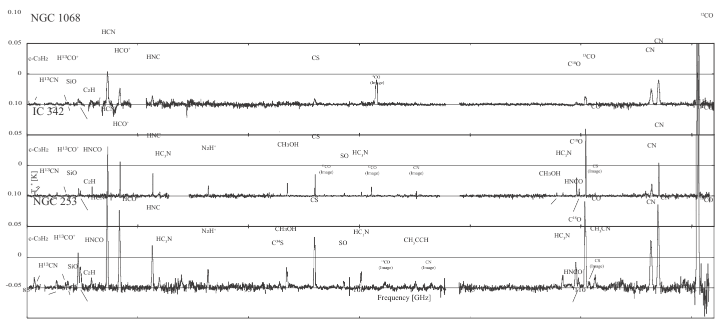
To date, about 40 molecular species have been identified in nearby external galaxies. As a result, it is now possible to study molecular abundances and chemical reactions in external galaxies. In fact, some groups have suggested that it is possible to diagnose power sources in dusty galaxies using molecular line ratios (e.g., [1-6]). The observations of the molecular gas chemistry of the active galactic nucleus (AGN) toward NGC 1068, one of the nearest galaxies with an AGN, have been reported by [2, 7-8]. However, further systematic observations of molecular lines are indispensable to study the impact of AGN on the interstellar medium. Therefore, we started a project to conduct a line survey in the 3-mm band of NGC 1068 using the new receiver in the 45-m telescope at Nobeyama Radio Observatory [9]. The beam size of this telescope (18″ at 86 GHz) is smaller than the size of the circumnuclear starburst ring in NGC 1068 (d∼30″), and it is therefore essential to study the impact of the AGN on the surrounding molecules; this will enable us to mitigate the contamination of the molecular lines from the circumnuclear starburst region in NGC 1068. We also observed NGC 253 and IC 342 to compare the effects of AGN and starburst on molecular abundance.

The observations at the 3 mm region (85–116 GHz) were carried out in 2009–2011. We successfully detected cyclic-C_3H_2 ($J_{Ka,Kc}$ = $2_{1,2}$–$1_{0,1}$), C_2H (N = 1–0) and $H^{13}CN$ (J = 1–0) for the first time in NGC 1068 [10]. We are also detected $H^{13}CO^+$, SiO, HCN, HCO^+, HNC, HC_3N, CH_3OH, CS, SO, ^{13}CN, $C^{18}O$, HNCO, ^{13}CO, CH_3CN, CN and ^{12}CO in NGC 1068. We obtained the abundances C_2H and cyclic-C_3H_2 relative to CS. As a result, we found no significant differences in the relative abundances between NGC 1068 and NGC 253. This result suggests that the basic carbon-containing molecules are either insusceptible to AGN, or are tracing cold ($T_{\rm rot}$ ∼10 K) molecular gas rather than X-ray irradiated hot gas. Moreover, we found low intensity ratios of N_2H^+ and CH_3OH relative to ^{13}CO and high ratios of CN, HCN and $H^{13}CN$ in NGC 1068 as compared with NGC 253 and IC 342. CN and HCN molecules are considered to be the X-ray tracers in theory.



The composite line spectra toward NGC 1068 (upper), IC 342 (center) and NGC 253 (lower). The intensity scale is in T_A^*.

References:

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P27

Star-formation types and molecular gas in nearby spiral galaxy NGC 253: suggestion for high-redshift star-formation activities

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Recent observations are confirming existence of two different star-formation types in both low-redshift and high-redshift galaxies. One is a long-lasting mode for star-formation in galactic disks ('disk'), and the other is a more rapid mode for starbursts ('starburst'). Those can be recognized from a fact that 'starburst' galaxies and 'disk' star-forming galaxies occupy distinct regions in the gas mass versus star-formation rate plane (e.g. Daddi et al. 2010). Origins and mechanisms of these two different star-formation types are, however, still under discussion.

We investigate differences between 'disk' and 'starburst' star-formation based on NGC 253 observation data. NGC 253 is a well-studied nearby barred-spiral galaxy. This galaxy is known as nearest and prototypical starburst; the strong infrared emission stands for a fact that intense massive star-formation activity has been taking place in the central region of this galaxy. NGC 253 also has disk star-formation; star-forming regions spread on its disk region and mainly associate to the "2-kpc ring". NGC 253 provides us unique opportunity to look into detail of the two star-formation types. We have already obtained ^{12}CO molecular emission line maps which cover both central region and disk region of NGC 253 using the Nobeyama 45-m radio telescope and the Atacama Submillimeter Telescope Experiment. Those maps show distributions of molecular gas and also enable us to obtain physical properties of molecular gas. Furthermore, thanks to recently obtained high-quality satellite-based ultraviolet and infrared data, we can assess precisely not only star-formation rate but also interstellar extinction (A_V) within the galaxy. Combining those data, we can discuss differences of characteristics between 'starbust' and 'disk' star-formation in spatial resolutions of less than 500 pc.

Our findings are as follows. 1) Star-formation rate to molecular gas mass ratios of the central region and the disk region mostly correspond to those of 'starburst' and 'disk'. Then we can assume that the central region and disk star-forming regions can represent 'strburst' and 'disk', respectively. 2) CO-to-H_2 conversion factor (X_{CO}) for the central region molecular gas is about three times smaller than that for the disk region gas. 3) Beam averaged molecular gas volume density in the central region is about ten times higher than that in the disk region. This is as expected and suggest that different initial mass function is not necessary for the 'starburst'. 4) Average ^{12}CO(3-2) to (1-0) line ratios for the central region and the disk region are 0.9 and 0.5, respectively. These values would be references for high-redshift galaxies observations.

P28

Distributions of Dusty Star Forming Region in Local Starburst Galaxies

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In recent years, many large deep cosmological surveys have revealed that the star forming rate (SFR) density of the universe (cosmic SFR density) increases by an order of magnitude from the present to $z \sim 1$. The densities at high redshifts are dominated by infrared bright galaxies, especially Luminous Infrared Galaxies (LIRGs; L_{IR} = L [8–1000 μm] = 10^{11}–10^{12} $L_\odot$) and Ultra Luminous Infrared Galaxies (ULIRGs; L_{IR} = 10^{12}–10^{13} $L_\odot$) (e.g., Goto et al. 2010). Their IR emission is thermal dust emission in the mid-IR (MIR) to far-IR (FIR) wavelength caused by absorbing UV photons from intensive star formation and/or luminous active galactic nuclei (AGNs). In order to know the detailed properties of these galaxies, and to understand how they are formed and evolved, local U/LIRGs are ideal laboratories for spatially resolved star-formation processes. However, U/LIRGs are affected by a large amount of dust extinction ($A_V > 3$ mag for LIRGs; Alonso-herrero et al. 2006), produced by their star formation activities. Then, hydrogen Paα (1.8751μm) represents a nearly unbiased tracer of the ongoing obscured SFR by its strength and relative insensitivity to the extinction. However, due to poor atmospheric transmittance around that wavelength, ground-based observations of Paα have been difficult so far.

ANIR is a near infrared camera for the University of Tokyo Atacama 1.0m telescope (miniTAO), installed at the summit of Co. Chajnantor (5640m altitude) in northern Chile (Yoshii et al. 2010). The high altitude and extremely low precipitable water vapor (PWV=0.5mm) of the site enable us to perform observations of Paα. The first light observation was carried out in July 2009, and Paα images have been successfully obtained using $N1875$ and $N191$ narrow-band filters. Galaxies listed in the catalog of IRAS-RBGS were drawn using a criteria with a velocity of recession of 2800 km/s $\sim$ 8100 km/s and 4.5×10^{10} $<$ L_{IR}(8–1000μm) [$L_\odot$] $< 6.5\times10^{11}$. In total, 38 objects were observed with $N191$ (for redshifted Paα), and H and K_s broad-band filters (for continuum) in June 2009–October 2011 (5 observation runs).

To quantify the morphology of local LIRGs, concentration index (Conselice et al. 2003) is used. The definition is C = 5 log (r_{80}/r_{20}), where r_{80} and r_{20} are the radii which contain 80% and 20% of the total flux, respectively. The total flux is defined as a flux contained within 1.5 times the Petrosian radius. We estimated C-Index for Paα line images (C_L; star-forming) and 1.9μm continuum images (C_C; stellar population). Our result shows quantitatively that there are two types of star-forming region profile of LIRGs (Figure 1). These facts suggest that the origin of the two star-forming modes is due to the difference in star forming process; Group-A is in the minor merging mode in which gas falls into center of elliptical-galaxy like potential, while Group-B is in the major merger mode.

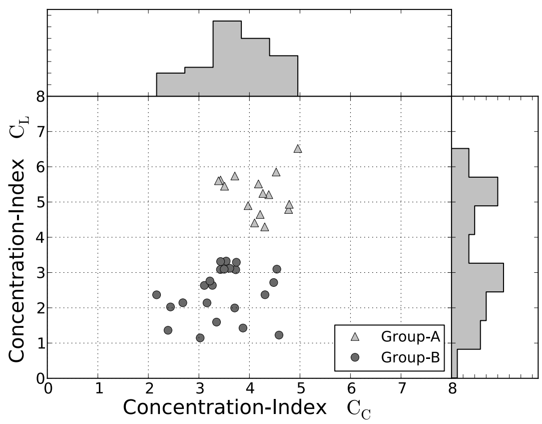

Figure 1: Comparison of C_L and C_C, where a bimodal distribution of Paα profile is seen.

In order to understand the details of the origin of these two modes, it is necessary to observe these galaxies which are classified into the two star-forming modes respectively by using CO($J = 1 - 0$) emission line that can reveal the gas mass, the morphology of gas, and the gas motion.

P29

NRO M33 All-Disk Survey of Giant Molecular Clouds (NRO MAGiC): Properties of Giant Molecular Clouds in M33

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We report the results of our observations of the ^{12}CO ($J = 1$–0) line emission in the Local Group galaxy M33. The observations have been conducted as part of the Nobeyama Radio Observatory M33 All-disk survey of Giant Molecular Clouds project (NRO MAGiC). The spatial resolution is 80 pc and the velocity resolution is 2.5 km/s. We identified 74 major giant molecular clouds (GMCs) within the galactocentric distance of 5.1 kpc. We present the GMC properties of size, velocity width, mass, degree of virialization, star formation rate, association of young clusters, and show discussions on them.

P30

Molecular Gas and Star formation in Giant HII regions of M33

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We have extensively studied the properties of molecular clouds which are associated with the super-giant HII region NGC 604 in the nearest (D = 840 kpc) spiral galaxy M33.

Massive star formation process in galaxies is one of unresolved important issues in recent galactic astronomy, because it governs the energy budget of galaxies as well as chemical evolution of galaxies. Despite of its importance, however, the formation process of massive stars remains unclear. In some galaxies there exist giant/superginat HII regions (hereafter referred to as GHRs). GHRs have high Hα luminosities of $\sim 10^{40}$ ergs s^{-1}, which corresponds to $\sim$ a few 100 O5 stars and provide us with an ideal environment to understand the clustered OB star formation process and their impact on the ambient interstellar medium (ISM). In other words, GHR can be “mini-starburst”, therefore, understanding the star formation process in these GHRs will be also important to study starburst phenomena in various galaxies. These GHRs are also crucial in the evolution of starburst in galaxies.

NGC 604 is the largest super GHR in M33 accompanied with massive molecular clouds and the central OB star cluster. Based on our results, we suggest that giant molecular cloud complex associated with NGC 604 is a unique laboratory for different, especially, for the early and intermediate stages along evolutionary path of star formation in the GHR (e.g. Tosaki et al. 2007, Miura et al. 2010). Then, the next questions are the internal structure of each GMCs and the variation of physical and chemical properties of dense molecular gas along evolutionary path of star formation.

We will discuss about the properties of molecular gas and star formation in the GHRs of M33.

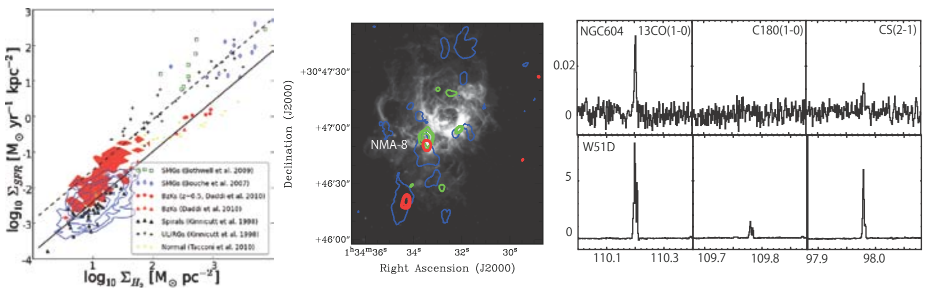

Figure 1: (left) The correlation between the surface densities of molecular gas (Σ_{H_2}) and the Star Formation Rate for GHRs (red filled contour) and for non-GHRs (blue contour) in M33, compared with that of other galaxies (Miura 2012). Data plots of other galaxies and lines are quoted from Daddi et al. (2010). The lower solid line is “Sequence of Disks”, and the upper dashed line is “Sequence of starburst”. We see that the plots for GHRs reach the ’“Sequence of starburst”. (middle) The ^{12}CO(1-0)(blue), HCN(red), 90 GHz (green) continuum superposed on Hα emission (Miura et al. 2010). (right) The ^{13}CO(1-0), C^{18}O(1-0), and CS(2-1) emission toward NMA-8 in NGC 604 (top) and W51D, an active star forming region in our Galaxy (bottom). We find significant decrease of C^{18}O with respect to CS in NMA-8 as well as in the center of W51D, despite the fact that we see rather normal ^{13}CO/CS ratios in these.

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Miura, R.E., 2012, PhD thsis, Universuty of Tokyo
Miura et al., 2010, ApJ, 724, 1120
Tosaki et al 2007, ApJL, 664, L27

P31

Spectroscopic Observations of YSOs in the Magellanic Clouds: Current and Future Studies

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Chemical diversity of materials that forms stars and planets in the universe is one of the great interests of present-day astronomy. Star-/planet-formation activities can occur in various kinds of galaxies which differ in many ways such as size, shape, and environment. Thus it is important to understand how galactic characteristics affect the properties of materials around YSOs.

The Large and Small Magellanic Clouds are the nearest low-metallicity galaxies to our Galaxy ($\sim$50 kpc for LMC, and $\sim$60 kpc for SMC). There are two main reasons to study YSOs in the Magellanic Clouds. First, YSOs in the Magellanic Clouds enables us to investigate how the different metallicity environments affect the properties of circumstellar materials. Metallicities of the LMC and the SMC are known to be approximately 1/2 and 1/5 compared to the solar neighborhood. Chemical evolution of the universe is, as a first-order approximation, the evolution of metallicity. In this respect, it is especially important to investigate YSOs in low-metallicity environments. Next, YSOs in the Magellanic Clouds enables us to investigate the properties of circumstellar materials by comparison with luminosity of the source thanks to their well-determined distances. Also, the face-on geometry of the LMC allows us to two-dimensionally compare the distribution of YSOs and the ISM. The above points are great advantages compared to observations of Galactic YSOs.

For the last few years, it has been pioneer days for spectroscopic studies of YSOs in the Magellanic Clouds. A number of embedded YSOs are spectroscopically identified in the LMC and SMC with *AKARI*, and their near-infrared ice features are discussed in detail. In addition, a large number of YSOs are also identified by the *Spitzer* observations, and mid-infrared ice features are investigated. Ices are considered to be a major reservoir of molecules such as water, carbon dioxide, and various organic compounds that are essential for the presence of life. We are going to discuss the properties of circumstellar ices around high-mass YSOs in the LMC and SMC based on infrared spectroscopic data. It is shown that ices around YSOs in the Magellanic Clouds possess different properties in terms of molecular abundances and column densities. The effect of galactic metallicity on the ice chemistry will be discussed in the presentation.

For the future, it is very interesting to focus on gas-phase species in circumstellar environments of Magellanic YSOs. Since sublimation of ices significantly affect the gas-phase chemistry, the unique ice chemistry in the Magellanic Clouds possibly affect gas-phase species. Thus interferometric observations of Magellanic YSOs should be one of the new trends in radio astronomy in the ALMA era. We also discuss the future possibilities of radio observations toward YSOs in extragalaxies.

X-ray irradiated dense molecular medium in the active nucleus of NGC 1097

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Investigation of dense molecular gas plays a key role in studying the nature of the dominant source of energy in galaxies such as active galactic nuclei (AGN) and starbursts. It is expected that the various heating mechanisms will produce different signatures in the molecular properties, e.g., photodissociation regions (PDRs) caused by intense UV radiation from massive stars and X-ray dominated regions (XDRs) formed near the very center of AGN[*1,2,3]. Cosmic rays from supernovae (SNe) and the injection of mechanical energy induced by the AGN jet or SNe (mechanical heating) are also important[*4,5]. To diagnose these energy sources by mm/submm spectroscopic observation is essential for the investigation of buried AGNs in dusty nuclei because these wavelengths do not suffer from dust extinction.

On the basis of these interests, many "key molecules" have been identified and proposed as a useful diagnostic tool for the dense interstellar medium (ISM) in galaxies by mm/submm spectroscopic observations. Among them, we have identified HCN enhancement with respect to HCO^+ and CO as the most promising indicator of the buried AGN[*6,7,8,9]. Also, some theoretical models predict high HCN abundance[*2,3,10]. However, some Seyferts do not show this enhancement possibly due to the lack of spatial resolution, i.e., low spatial resolution spectral surveys can not resolve the inner central structure of nearby active galaxies, where both AGN and starburst often coexist within a few 100 pc scales. Therefore, one may observe a mixture of dense molecular clouds with different physical and chemical properties. Clearly, interferometric high spatial resolution observations are needed.

Therefore, we have conducted an observation towards the nucleus of a type-1 Seyfert, NGC 1097 ($L_{2-10\mathrm{keV}} = 3.7 \times 10^{40}$ erg s^{-1} [*11]), in ALMA Cycle 0[*12] at Band 7. The array configuration was a compact one with 16 antennas, and the resulting spatial resolution was $\sim$ 1".5 $\times$ 1".2. We achieved r.m.s. noise level of $\sim$ 2 mJy (velocity resolution is $\sim$8 km/s) with the on-source time of only $\sim$ 1 hr. The results of this observations are summarized as follows. (1) We detected the strong HCN(J=4-3) emission and the HCN/HCO^+ line ratio is over 1, which is a similar value to the low-J results. (2) The most surprising result is an extremely high HCN(J=4-3)/CS(J=7-6) line ratio, which is over 10. A similar ratio ($\sim$30) is also found in the luminous AGN galaxy, NGC 1068. However, these extremely high line ratios have never been observed in starburst galaxies and star-forming regions (e.g., $\sim$3.5 in NGC 253[*13,14] and $\sim$1.7 in Ori-KL[*15]). (3) No vibrationally excited HCN emission, HCN(v_2=1, J=4-3) has been detected in this galaxy, whose nucleus is not IR luminous. However, strong HCN(v_2=1, J=4-3) emission has been reported in the IR luminous galaxy, NGC 4418[*16]. This indicates that the amount of the HCN(v_2=1, J=4-3) might simply depend on IR luminosity.

Considering these results, we conclude that the HCN abundance is strongly enhanced in the nucleus of NGC 1097 and the HCN/CS line ratio is a very effective discriminator between AGN and starburst.

References:

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P33

Wide-field ^{12}CO (J=1–0) imaging of the nearby barred galaxy M83 with the NMA and the 45m telescope

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We present results of the mapping observations of the nearby barred spiral galaxy M83 in ^{12}CO (1–0) carried out with the Nobeyama Millimeter Array (NMA). To correct for the lack of sensitivity to diffuse emission, the interferometric data are combined with the data taken with the Nobeyama 45m telescope. Target field of the observations consists of 46 pointings and covers the entire extent of the molecular bar and part of the spiral arms. Galactic structures are resolved with a spatial resolution of $\sim$ 100 pc $\times$ 200 pc and several inter-arm clouds are also detected.

'Classic' density wave theory along with the galactic shock model predict that galactic structures will organize the progress of star formation (SF) through agglomeration and compression of molecular material. In this picture, distribution of molecular clouds (MCs) and young stellar populations should show a rather coherent pattern which goes from upstream to downstream on the rotating frame. However, in recent, some observational evidences against this rather simple picture have been reported (e.g, Foyle+11), and the picture of persistent galactic structures, which is a starting point of 'classic' density wave theory, is also been attacked by numerical simulations (e.g., Wada+11). Re-examination of the relation between MCs and SF regions are thus highly required. Barred galaxies offer a unique opportunity in that it is known to show a variety of star forming activity within a single galaxy.

Here, taking advantage of the spatial resolution and sensitivity to the diffuse gas clouds, relations between molecular gas and star forming regions are examined to see whether galactic structures in the inner disk of M83 exert influences on progress of star formation. Two characteristics are found with the combined (NMA+45m) data: 1) star formation efficiency (SFE) is found to be lower by about factor of two inside the bar compared to outside of the bar, and 2) young star forming regions tends to be preferentially located at the leading side of gas clouds, at least within the bar and near both ends of the bar. Gas kinematics are representative of non-circular motion induced by the 'slowly' rotating bar. The bar-induced kinematics of molecular clouds is likely to be responsible for the SF characteristics: short dynamical time scale within the bar, which is comparable to the life time of GMC, suppress the SFE within the bar, and the large relative velocities between MCs and underlying stellar bar due to the slow pattern speed give rise to the moderately organized pattern of star formation.

P34

Expected Observations of Star Formation Process: from Molecular Cloud Core to Protostar Phase

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We did MHD simulations of the contraction of rotating, magnetized molecular cloud cores. In the molecular cores, B-field and angular momentum (J) vector are not always aligned. When a first hydrostatic core forms, axisymmetric structure appears and average B and J are parallel in small scale. However, in large scale, the configuration is far from this. This means that contraction process is imprinted on the snapshot. We calculated two mock observations of MHD simulations

1. the polarization from thermal dust emission to reveal the magnetic evolution (Kataoka et al. 2012; Shinnaga et al. 2012; Tomisaka 2011) and

2. the line emissions from interstellar molecules to reveal the evolution of density and velocity (Tomisaka and Tomida 2011; Tomida et al 2011).

Comparing the mock observations with true ones, we can answer several questions: in which case the hourglass-shaped and S-shaped magnetic fields are seen; how the distribution of polarized intensity is understood; how the first hydrostatic core should be observationally identified.

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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.

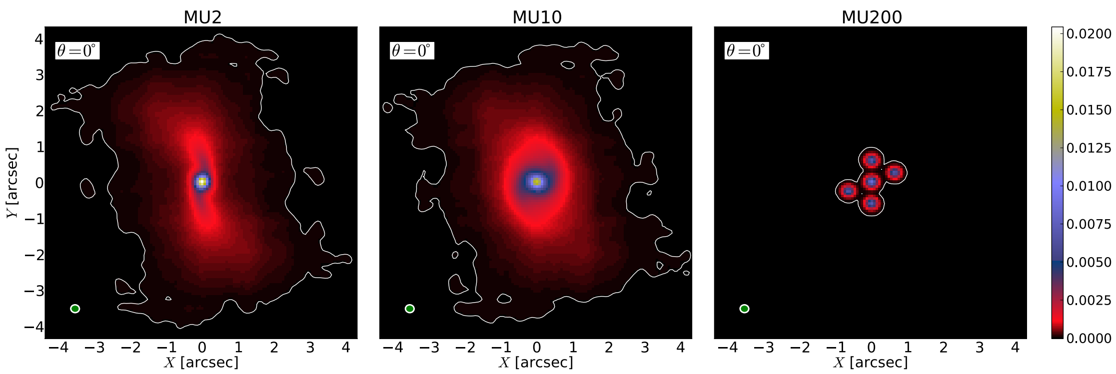

Figure 1: Simulated band 3 observation of a collapsing protostellar dense core with ALMA in configuration 20, viewed face-on. From left to right, the figures correspond to models with a decreasing magnetic field strength. Color scales are in Jy/beam and the size of the synthesized beam is shown in the 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.

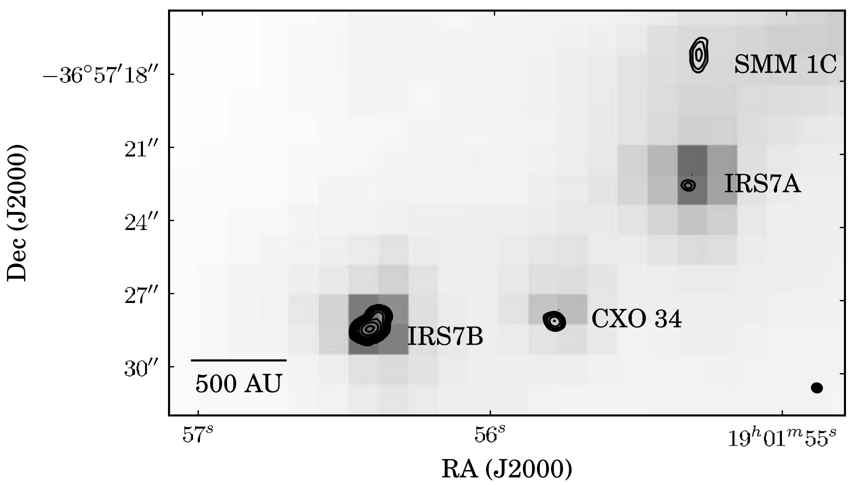

Figure 1: ALMA 0.87 mm continuum (logarithmically spaced contours; Lindberg et al., in prep.) and *Spitzer* 4.5 μm image (greyscale). The ALMA beam size ($0\farcs41 \times 0\farcs37$) is shown in the bottom right corner. Previously only IRS7B and SMM 1C have been detected in the submillimetre.

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 $\times10^{-10}$, 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 $\times10^{-10}$, 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.

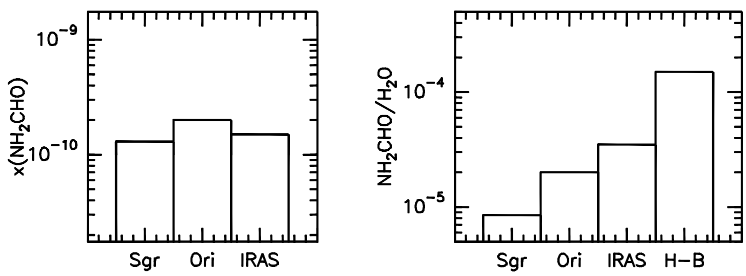

Fig.1 *(left)* Formamide abundances in SgrB2 (Sgr), Orion-KL (Ori) and IRAS16293-2422 (IRAS) ; *(right)* Formamide abundances relative to H_2O in the same sources and in the Hale-Bopp comet (H-B). The H_2O abundances come from Polehampton et al. 2007, Melnick et al. 2010 and Coutens et al. 2012 for SgrB2,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

References:

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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.

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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 extra-galactic 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 $22 \pm 29\ M_{\odot}$, comparable to its virial mass of $56 \pm 36\ M_{\odot}$, 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 $26 \pm 23,\ 11 \pm 15,\ \text{and}\ 35 \pm 27\ M_{\odot}$, 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).

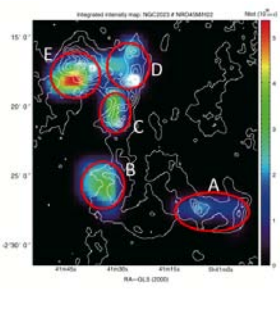

Figure 1: NH_3 total column density map (color) superposed on the 850 μm dust continuum map (contour). The color bar on the right-hand side of the panel shows the column density scale in $10^{14}\ cm^{-2}$ The contour intervals are 0.2 mJy beam^{-1}, starting from 0.01 mJy beam^{-1}. The red lines indicate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

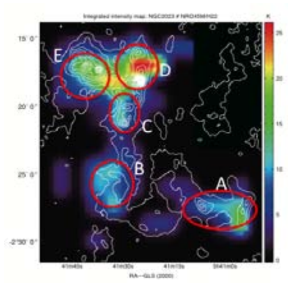

Figure 2: Temperature map (color) on the 850 μm continuum one (contour). The color bar on the right-hand side of the panel shows the temperature scale in K. The parameters of the contours are the same as in Figure 1.

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.

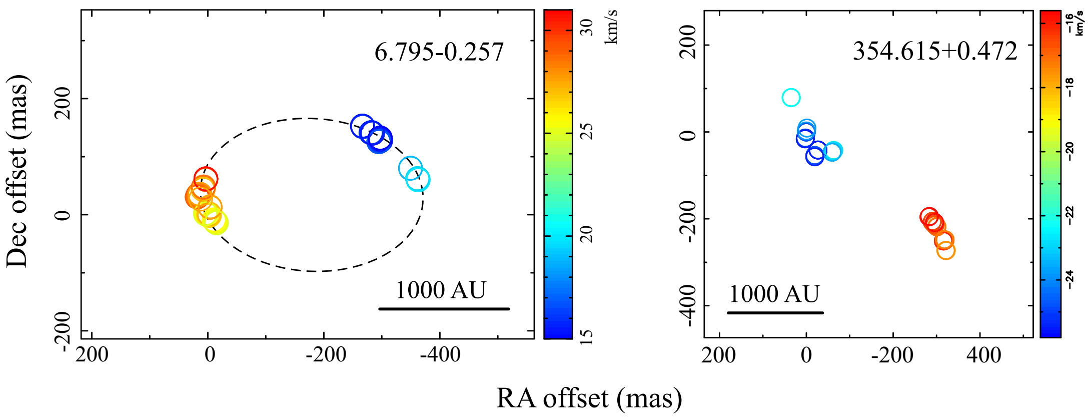

Figure 1. Spatial distributions of the 6.7 GHz methanol maser spots as target sources in this proposal observed using the EAVN in August 2010 (left: G6.795−0.257 (ellipse), right: G354.615+0.472 (linear)). In each panel, the spot sizes are fixed and the color indicate its radial velocity (see color index 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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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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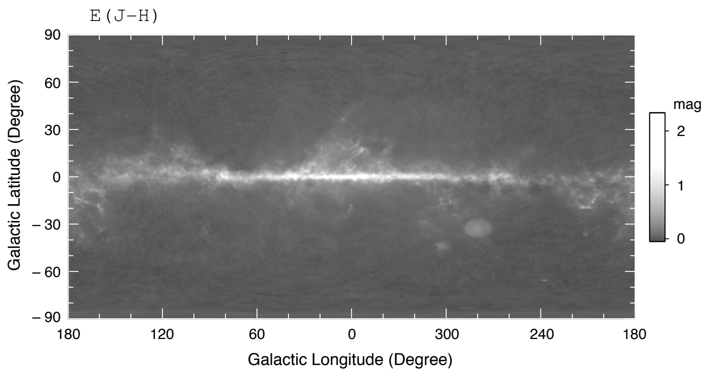
We have applied a correction to the large scale color excess maps of $E(J-H)$ and $E(H-K_\mathrm{S})$ derived by Dobashi (2011) based on the 2 Micron All Sky Survey Point Source Catalog (2MASS PSC; Skrutskie et al. 2006). These maps were produced using a new technique named X percentile method, and they cover all of the sky at the $1'$ grid with a deep threshold magnitude set of $(m_J, m_H, m_{K_\mathrm{S}}) = (16.0, 15.5, 15.0)$ 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 $\sim 7.7\times10^8$ 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 ~ 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.

P61

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.

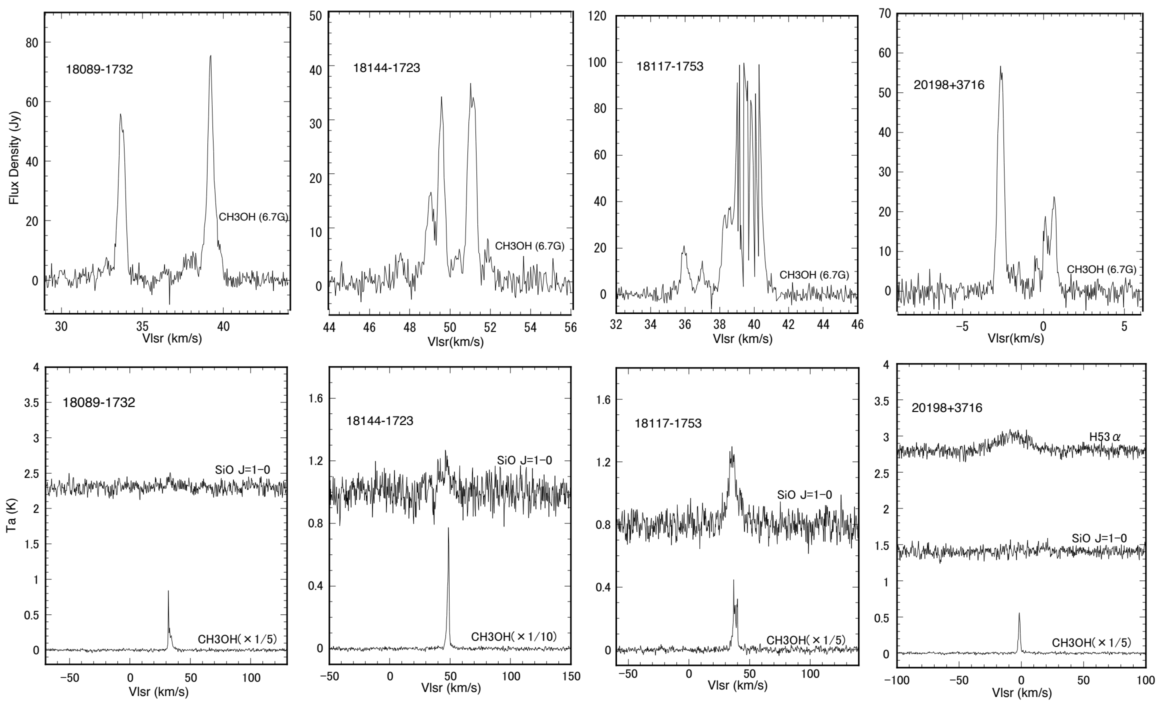

Figure 1: The spectra of the sources in both of classes were detected.

P64

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.).

P66

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, $\sim 2.0\times10^{-3}$ 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.

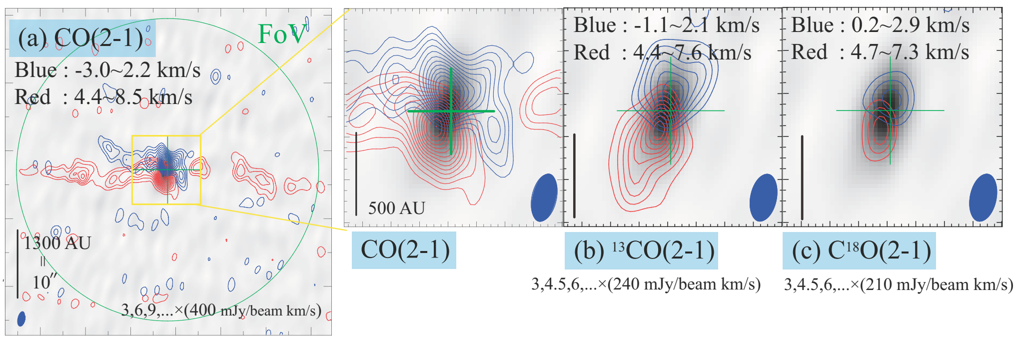

Fig. 1 : (a) High velocity components in the SMA CO(2–1) emission. (b) (c) High velocity components in the SMA ^{13}CO(2–1) and C^{18}O(2–1) emission, respectively. Gray scales are the 1.3 mm dust continuum maps.

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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.

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..

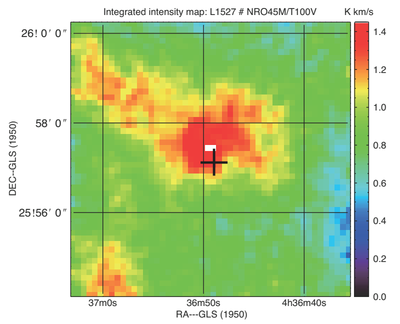

Figure ; The integrated intensity map for $C^{18}O$. Cross marks the position of protostar IRAS04368+2557.

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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 (υ = 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.

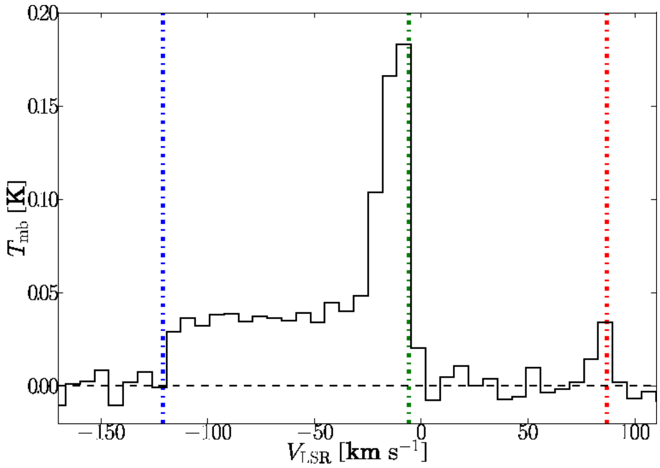

Figure 1: The SiO (υ = 0, J = 2–1) spectrum taken by NRO 45m in $T_{\rm mb}$ scale. The blue and red dotted line indicates the most red (+87 km s^{-1}) and blue-shifted (-120 km s^{-1}) maser component, respectively. The systemic velocity of -5 km s^{-1} is also indicated by the green dotted line. The 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 $\sim$500 K. Then the gas abundances in the warm envelope and outer layers of the first core ($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.

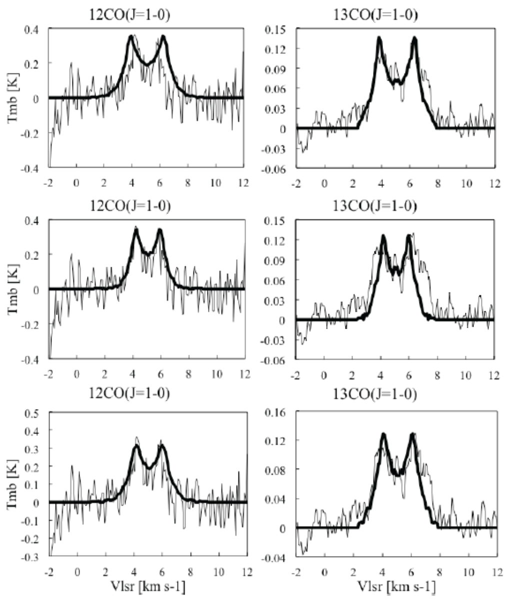

Figure 1: Comparison among model fitting results. Fitting by power-law model in the case of ^{13}CO (J=1–0) best fitting (top), fitting by power-law model in the case of ^{12}CO (J=1–0) best fitting (middle), and the best fitting by similarity solution model (bottom). Thin lines show the observed spectra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

References

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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 $r < 20\mathrm{AU}$ or in the gap ($39 - 65$ AU).

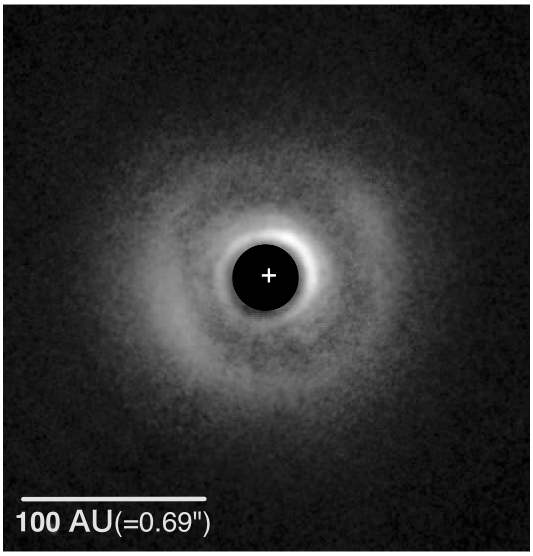

Figure 1: PI image with HiCIAO. Black area and white cross indicate the masked region and stellar position, respectively.

References:
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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.

References:

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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.

P82

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.

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).

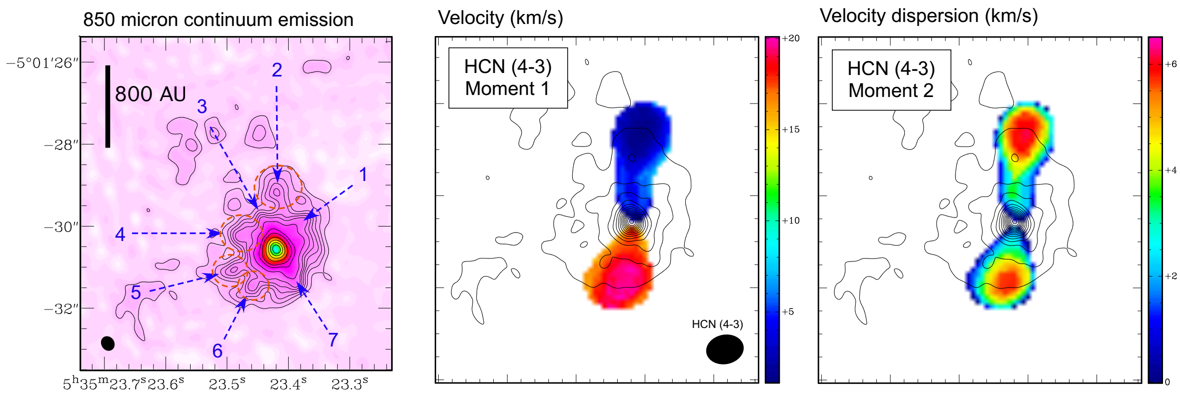

Figure 1: **Left:** 850 μm continuum image obtained with the SMA all configuration data. Dashed circles with numbers show the positions of spiky structures and possible clumps. **Center & Right:** Velocity structure and velocity dispersion of the molecular outflow associated MMS-6 main obtained with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

P86

A new "off-point-less" method for mm/submm spectroscopy with a frequency-modulation local oscillator

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We have been developing a new method for mm and submm spectroscopy with a *frequency-modulation local oscillator* (FMLO), which adds a new powerful option to the conventional schemes such as the *position-switching* and *frequency-switching* methods. The FMLO method has a potential to dramatically improve the sensitivity of single-dish spectroscopic observations, by just changing the way of controlling the receiver system. The noise removal technique that the FMLO method employs is similar to that used in continuum deep surveys and CMB cosmological experiments using multi-pixel bolometer cameras; If we consider the one-to-one relations between multibeam imaging observations and spectroscopic one, "pixels of a camera" → "channels of a spectrometer" and "rapidly moving the field of view" → "quickly changing the observing frequency (with a FMLO)", then the technique can be applied to spectroscopic observations. We have implemented a new FMLO control system on the ASTE 10-m telescope, which demonstrates that the FMLO method does work for (1) minimizing the overheads and maximizing the observing throughput, (2) removing of $1/f$-type correlated noises, (3) removing spectral baseline ripples, and (4) separating sidebands, as shown in Figure 1.

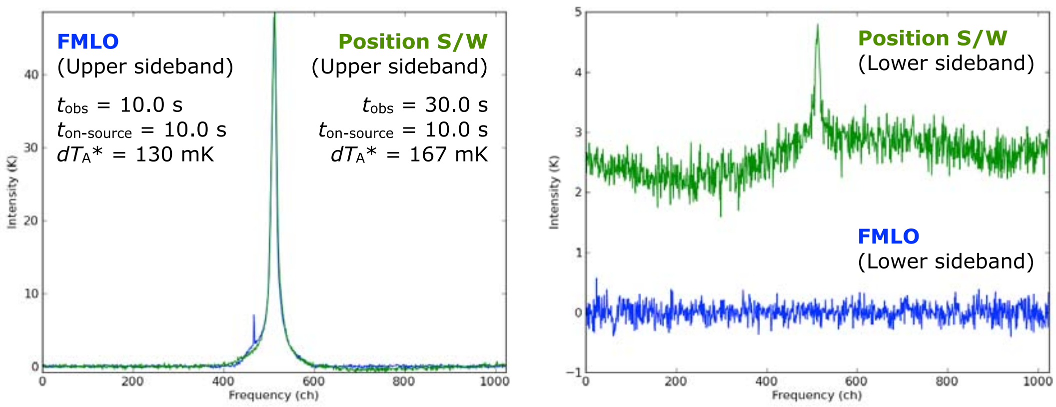

Figure 1: ***(left)*** The 345 GHz upper sideband spectra of ^{12}CO (3–2) toward the Ori A molecular cloud taken with the FMLO (blue curve) and position-switching (PSW) methods (green curve) implemented on ASTE, which demonstrates that the FMLO spectrum is 2.2× more sensitive than PSW for fixed total observing time ($t_{\rm obs}$) including any overheads, and is 4.9× more efficient than PSW for fixed noise level ($dT_{\rm A}^{*}$). The band width and frequency resolution are 512 MHz and 0.5 MHz, respectively. A spike seen in the red wing is presumably a ^{12}CO (3–2) in the Earth's stratosphere. ***(right)*** The 333 GHz lower sideband spectra across the image sideband of ^{12}CO (3–2) shown in the left panel. While the spectrum taken with the PSW method is by the CO line leaking from the upper sideband and baseline fluctuations, that taken with the FMLO technique provides a fairly flat baseline with no contamination of the image sideband since frequency modulation smears out image-sideband line features.

P87

A New 45 GHz Band Receiver with Dual Polarization for NRO 45-m Telescope

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Write your abstract here. We are currently developing the 45 GHz band, dual polarization receiver to be mounted on a Nobeyama 45 m radio telescope. In this presentation, we report on the current status of development of the new dual polarization receiver. In the process of star formation, the magnetic field is considered to play an important role. However, our understanding of the importance of magnetic field in star formation is only poorly understood because of the lack of the accurate measurement of the magnetic field strength in molecular cloud cores. To shed light on the issue of the magnetic field, we plan to directly measure the magnetic field strength using the Zeeman effect of a molecular line, CCS ($J_N = 4_3 - 3_2$) which is abundant in the pre-protostellar phase. However, the Zeeman shift is anticipated to be around 60 Hz, and therefore Stokes V is so weak, about 0.3 % of I at narrow line width of 0.3 km s^{-1}. For this purpose, a receiver capable of receiving two circularly polarized waves with high sensitivity is the key to success this project.

In development of cooled receiver, optics and polarization splitter are required. First, we designed an optical system for guiding the condensed signals at the antenna to the receiver. As much as possible by increasing the size of the metal mirror used in the optical system, we have to reduce the spillover loss. Moreover, to minimize the beam angle bend in the ellipsoidal mirror, achieving low cross polarization coupling. Second, separating polarization, we design an orthomode transducer (OMT). As a result of measurement, the OMT performed return loss of less than 20 dB, cross polarization coupling of better than 30 dB and insertion loss of less than 0.3 dB across the observational band. For future, we will install a cooled receiver to 45m radio telescope, we will try the polarization observation.

Optimization by Smoothed Bandpass Calibration in Radio Spectroscopy

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We have developed the Smoothed Bandpass Calibration (SBC) method and the best suitable scan pattern to optimize radio spectroscopic observations. Adequate spectral smoothing is applied to the spectrum toward OFF-source blank sky adjacent to a target source direction for the purpose of bandpass correction. Because the smoothing process reduces noise, the integration time for OFF-source scans can be reduced keeping the signal-to-noise ratio. Since the smoothing is not applied to ON-source scans, the spectral resolution for line features is kept. An optimal smoothing window is determined by bandpass flatness evaluated by Spectral Allan Variance (SAV). An efficient scan pattern is designed to the OFF-source scans within the bandpass stability timescale estimated by Time- based Allan Variance (TAV). We have tested the SBC using the digital spectrometer, SAM45, on the Nobeyama 45-m telescope. The optimal smoothing windows were determined as 501, 28, 18, and 4 ch for bandwidths of 2000, 500, 125, and 15.6 MHz, respectively. The optimal scan pattern was designed as sequences of [60-s ON + 10-s OFF] and [48-s ON + 16-s OFF] scan pairs for narrow and wide bandwidth, respectively. The noise level with the SBC was reduced by factors of 1.8 and 1.3 compared with the conventional method. We also found sporadic instability (bursts) in the total power and spectra in IF during the test observations. Although the bursts significantly distorts the resultant spectra, we found a solution to cancel the spectral variation by decomposing them into static and burst components. This solution can be a hint to ease spectral flagging processes and to bring better efficiency in integration time.

P89

ALMA Extended Array

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We propose to append five 12-m antennas within 300-km to realize high angular resolution of < 1 mas and sensitivity to detect $T_{\rm b} < 1000$ K. This ALMA extended array offers a new parameter space of "Thermal universe with VLBI resolution". Proposed science case includes black-hole formation in sub-mm galaxies, mass accretion processes onto protostars, imaging stellar photospheres, distance measurements of stars, and so on. The array also functions as a part of sub-mm VLBI that targets black- hole imaging, and contributes to establish technologies on sub-mm coherence that is critical for the ALMA enhanced array. In the symposium we discuss about technical and practical issues to realize the plan.

P90

Polarization calibration plans for single-dish radio observations

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We report our polarization calibration plans for single-dish radio telescopes. Polarization observations offer unique astronomical properties such as magnetic fields and plasma composition. To measure polarization properties, dual polarization signals such as right- and left-hand circular polarizations, must be received individually. Since cross talk and delay between orthogonal signals affects accuracy in polarization measurements, detailed calibration plans are crucial. We propose a polarization calibration plan using a digital cross correlator between orthogonal polarizations, a digital spectrometer. An absorber covering the feed horn is used as a delay calibrator and also as an unpolarized source. Test observations were performed using the VERA Mizusawa station at 22 GHz. We observed absorber, unpolarized sources (Jupiter, 3C 84, and NGC 7027) and some linearly polarized sources (3C 286, 3C 345, 3C 279 and Orion KL) in various parallactic angles and field rotator angles. We applied delay calibration by using cross correlation function toward absorber. We decomposed into the optics-originated and electronic D-term by using different phase responses between right- and left-hand circular polarizations. And we estimated the polarization degree of the outbursting water maser of Orion KL as 58.6%. In our talk we will present our calibration processes and polarization performances for single-dish observations.

P91

ALMA Science Verification in the EA Imaging Team

DANIEL ESPADA, YASUTAKA KURONO, SHINYA KOMUGI, ALFONSO TREJO, SATOKO TAKAHASHI, ERIK MULLER, KOUICHIRO NAKANISHI, MASAO SAITO, KEN'ICHI TATEMATSU, SATORU IGUCHI, TETSUO HASEGAWA, NORIKAZU MIZUNO, DAISUKE IONO, SATOKI MATSUSHITA, EDWIGE CHAPILLON, YU-NUNG SU, AKIKO KAWAMURA, E. AKIYAMA, M. HIRAMATSU, HIROSHI NAGAI, TSUYOSHI SAWADA, AYA HIGUCHI, KENGO TACHIHARA, KAZUYA SAIGO, S. ASAYAMA, AND TAKESHI KAMAZAKI

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I will summarize in this talk the Science Verification (SV) process used to demonstrate that ALMA data is valid. The list of SV sources was designed to achieve interest in the whole astronomical community, from protoplanetary systems such TW Hya to the BR1202 high-z system, and the data is regularly released for public use via the ALMA science portal in http://almascience.nao.ac.jp/alma-data/science-verification. I will focus my presentation on SV projects where the East Asian Imaging team (including NAOJ and ASIAA) has had a direct contribution in the observation design, data reduction, and validation, in collaboration with the Joint ALMA Office, North America and European Imaging Teams. These include main array interferometric data of IRAS 16293 at band 9 (multiple lines), Antennae galaxies CO(2–1) and CO(3–2), NGC5128 CO(2–1), and BR1202 CII and band 7 continuum data. I will also present the demonstration on the new Cycle 1 capability of zero and short spacings obtained using the Atacama Compact Array (ACA), and its combination with data obtained with the main array. During the talk I will review some exciting scientific results recently obtained with these SV data that had not been previously been detected due to lack of sensitivity/resolution in previous observations, such as a newly discovered molecular arm likely of tidal origin in the south of the Antennae galaxies.

P92

Astronomical Verification for ALMA Array Element

S. Asayama[1], L.B.G. Knee[1], P.G. Calisse[1], P.C. Cortes[1], C. Lopez[1], T. Nakos[1], N. Phillips[1], Kurt Plarre[1], M. Radiszcz[1], R.S. Simon[1], G. Siringo[1], H. Yatagai[1], R. Jager[1], B. Lopez[1]

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The ALMA System Integration Science Team (SIST) is a group of scientists and data analysts whose primary task is to verify and characterize the astronomical performance of array elements (individual, fully equipped antennas) as single dish and interferometric systems.

The full set of tasks is required for the initial construction phase verification of every array element, and these can be divided roughly into fundamental antenna performance tests (verification of antenna surface accuracy, basic tracking, switching, and on-the-fly rastering) and astronomical radio verification tasks (radio pointing, focus, basic interferometry, and end-to-end spectroscopic verification). These activities occur both at the Operations Support Facility (OSF: just below 3000 meters elevation) and at the array operation site (AOS) at an elevation of 5000 m above sea level.

P93

3-d modeling of interferometric data cubes

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ALMA, and other instruments planned in the next decade, will produce data cubes with high spectral and spatial dynamic range. For many sources, this now permits or even demands more sophisticated modeling with 3-d radiative transfer tools. We describe a pipeline we have created to do this in a semi-automated fashion, and illustrate this with modeling results of SMA and HIFI data of SgrB2.

P94

Antenna Surface Measurements Using Astronomical Sources

SAMANTHA KAJ BLAIR[1], RICHARD HILLS, AND ROBERT LUCAS

[1] ALMA

wavelength of the incoming signal in order to collect signals with high efficiency. For observations at sub-millimeter wavelengths it is therefore critical to have extremely accurate means of measuring antenna surfaces and for monitoring their deformations under a range of conditions.

We have made measurements of the surfaces of the ALMA antennas using signals from astronomical sources, typically bright quasars. We are able to employ the full power of the interferometer array for this purpose, using some of the antennas to provide phase and amplitude reference signals while scanning the antennas under test in a raster pattern. Fourier inversion of the resulting measurement of the complex beam pattern yields a map of the errors in the wavefront at the aperture. We call this method "astro-holography" in order to distinguish it from holographic antenna measurement techniques using man-made transmitters. Astroholography has many advantages over other techniques: the signals that are being used to measure the accuracy of the surface are the same as those for which the antenna is going to be used in operation; the entire system (main reflector surface, the secondary mirror, receiver and membrane) are all included, and these measurements also give information about the alignment of the optics; and the measurements are being made under the real conditions that will encountered in practice including varying elevation angle, temperature and thermal radiation.

The poster will present data showing that, under very good conditions, the repeatability in the measurements can approach the level of 1 micron rms. It will also demonstrate that the deformations in the surface due to gravity are easily detected and that other changes, probably due to thermal effects are also seen.

P95

ALMA Science Verification results

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P96

The Japanese VLBI Network

K. Fujisawa[1], JVN collaboration

[1] Yamaguchi University, Japan.

A VLBI network, called the Japanese VLBI Network (JVN) has been established in Japan since 2005 (JVN Web Site, http://www.astro.sci.yamaguchi-u.ac.jp/jvn/). The JVN consists from 13 telescopes; the VERA (NAOJ), Tomakomai 11m (Hokkaido university), Gifu 11m (Gifu university), Yamaguchi 32m (NAOJ, Yamaguchi university), Kashima 34m (NICT), Tsukuba 32m (GSI, Tsukuba university), Usuda 64m and Uchinoura 34m (ISAS/JAXA), and Ibaraki 32m (NAOJ, Ibaraki university). Six of the thirteen telescopes are connected with a high-speed (2Gbps) e-VLBI network based on the SINET4 by National Institute for Informatics (NII). The JVN is operated under cooperation of NAOJ and seven universities in Japan, with supports from ISAS/JAXA, NICT and GSI. The length of baselines ranges from 50 km (Kashima - Tsukuba) to 2500 km (Tomakomai - VERA Ishigaki).

We show two of scientific results obtained with the JVN. Some class of AGNs with relatively low flux density (mJy level), such as narrow-line Seyfert 1 galaxies (NLS1) and broad absorption line quasars (BAL quasar), have been observed and studied with the JVN. Some sources of these classes exhibit relatively high Doppler boosting, although these classes of AGN are tend to be radio-quiet (Doi et al. 2007, Doi et al. 2009). Methanol maser at 6.7 GHz is one of the main targets of the JVN. A VLBI observation of Cepheus A (Cep A) revealed the elliptical distribution of the maser spots around a high-mass young stellar object (HW2) (Sugiyama et al. 2008). We have made a monitoring observation of Cep A and detect the internal motion of the maser spots; the motion was a combination of the rotation and infalling motion toward the central star.

We think that it is important for JVN to collaborate with countries of east-Asia; Korea, China and Taiwan. To combine the JVN with their own networks (KVN and CVN), a powerful VLBI network will be constructed as East-Asian VLBI Network (EAVN). Test observations have been started and preliminary images are already obtained.

References

Doi, A. 2007, PASJ, 59, 703
Doi, A. 2009, PASJ, 61, 1389
Sugiyama, K. et al. 2008, PASJ, 60, 1001

P97

VLBI Monitoring Programme of AGN Jets in Japan and Future Prospects for Mm/submm VLBI

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*

The location of high energy emission and its production mechanism are long standing problem in the physics of active galactic nuclei (AGN) jets. While a number of competing models have been proposed, the γ-ray emission mechanism and the location of emitting region are still disputed. Quasi-simultaneous multiwavelength study is a key to discriminate such models. Here we present an intensive VLBI monitoring programme towards the AGN jets, so-called GENJI programme. Currently, we are monitoring 8 notable AGNs including different subclass of AGN (flat spectrum radio quasars (FSRQs), BL Lacs, and radio galaxies) once per two-weeks using VERA at 22 GHz (Fig. 1). Typical angular resolution is about 1 milli-arcsec, which allows us to resolve the central pc-scale region in the nearby AGNs. We have successfully coordinated follow-up observation right after the γ-ray flares in three AGN (3C 454.3, NRAO 530, and PKS 1510-089). The radio core, which is identified as the brightest point on the VLBI image, shows flux increase at 22 GHz some time after the γ-ray flare. This delayed flux increase in radio band indicates that the γ-ray emitting region is presumably opaque at this frequency range. On the other hand, it is reported that mm/submm light curve shows a good correlation with the γ-ray flare particularly in 3C 454.3. Mm/submm VLBI is a promising method to probe the γ-ray emitting region directly and will give a strong constraint on the physics of high-energy emission and particle acceleration. Phase-up ALMA will be a key technique to achieve the mm/submm VLBI.

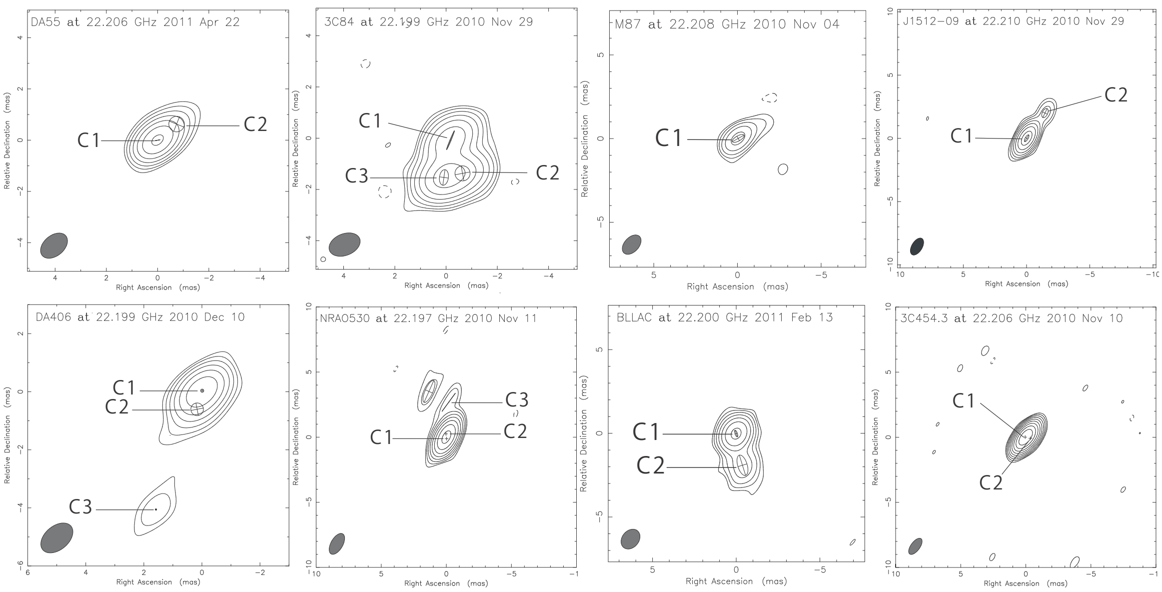

Fig. 1: Contour plots of total intensity of GENJI sources at 22 GHz.

P98

Development of 32-m Radio Telescopes for Monitoring Observations of Methanol Masers, H_2O Masers, and Radio Continuum

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[1] Ibaraki University, Japan.
[2] Osaka Prefecture University, Japan. [3] Yamaguchi University, Japan. [4] Gifu University, Japan.
[5] Hokkaido University, Japan. [6] University of Tsukuba, Japan. [7] Kagoshima University, Japan.
[8] National Astronomical Observatory of Japan, Japan. [9] Shanghai Astronomical Observatory, China.

Star formation is frequently accompanied with masers and radio continuum emission with strong variability. Class II methanol masers (including 6.7 GHz) are one of the best probe to study the environment around massive young stellar objects such as disk and outflow. H_2O masers are also used to probe jet and/or outflow. Monitoring observations of the intensity and velocity are already made by several groups (e.g., Goedhart et al. 2004; Fujisawa et al. 2012), but the observing intervals are one day or more. More frequent observation will reveal the activity associated with smaller scales.

Takahagi and Hitachi 32-m antennas, which have been used for satellite communications at 4 and 6 GHz by KDDI, were decommissioned in March 2007. These antennas were transferred from KDDI to NAOJ in January 2009, and now belong to the Ibaraki station, which is a branch of Mizusawa VLBI Observatory of NAOJ. We, NAOJ and Ibaraki University, in cooperation with other institutes such as ISAS/JAXA, NICT, GSI, and universities (Hokkaido Univ., Univ. Tsukuba, Gifu Univ., Osaka Prefecture Univ., Yamaguchi Univ., and Kagoshima Univ.) have decided to use these antennas for VLBI network (Japanese VLBI Network: JVN; East-Asia VLBI Network: EAVN). We will use these antennas not only for VLBI observations but also for single dish and 2-element interferometric observations.

We are using the cooled receiver systems covering 6.5–8.8 GHz, whose system noise temperature was measured to be $\sim$20 K, including atmosphere toward zenith, and the room-temperature 22 GHz receiver, whose system noise temperature including atmosphere toward zenith was $\sim$250 K. We are now developing cooled receiver system at 22 GHz. The pointing accuracy is $\sim$0.4 arcmin, which is measured by the observations of strong radio continuum sources such as 3C273 at 8 GHz. The aperture efficiency is measured to be 55–75 at 6.7 and 8 GHz, and $\sim$30% at 22 GHz. The spectrometer system using K5/VSSP32 was installed for single dish observations (Fig. 1). We succeeded first scientific VLBI imaging observations at 6.7 GHz in August 2010, with 6 antennas (VERA$\times$4, Shanghai, and Hitachi) participated (see the presentation by K. Sugiyama et al.). We also achieved "first fringe" in June 2012 between Takahagi and Tsukuba at 22 GHz using IP-VLBI system. We are now testing two-element array using Hitachi and Takahagi antennas (Fig. 2). We acknowledge NICT for the use of correlation software.

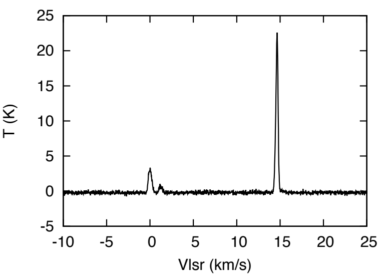

Fig. 1. Sample spectrum of 6.7 GHz methanol maser toward ON1 obtained at Hitachi telescope. Integration time is 10 min. and sampling is 4 bit.

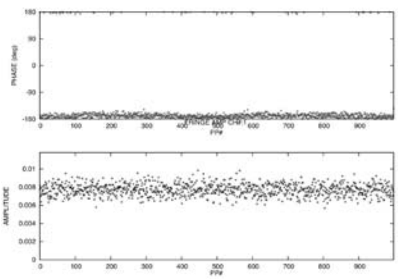

Fig. 2. Fringe phase and amplitude obtained by the Hitachi-Takahagi two-element array toward NRAO512 at 6.660–6.676 GHz (10 min, 4 bit).

References: Goedhart, S. et al. 2004 MNRAS, 355, 553; Fujisawa, K. et al. 2012, PASJ, 64, 17

P99

Test observations of a new 100 GHz wave-band FOur-beam REceiver System on the Nobeyama 45-m Telescope (FOREST)

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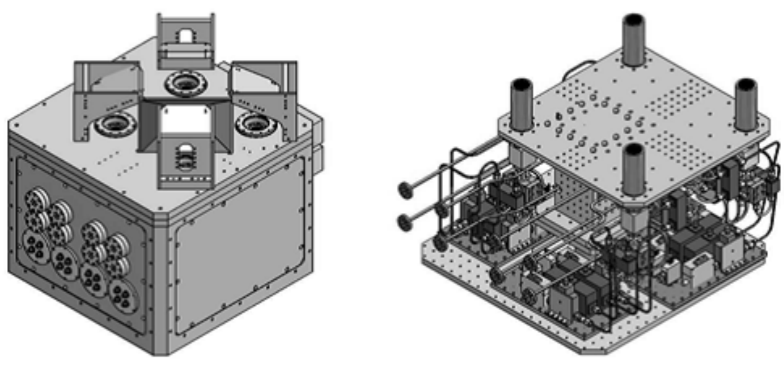
[6] The University of Tokyo, Japan.

We report results of test observations of a new 100 GHz wave-band FOur-beam REceiver System on the Nobeyama 45-m Telescope (FOREST) from 2012 April to June.

The FOREST consists of four waveguide-type dual-polarization sideband-separating SIS mixer receiver systems of 100 GHz wave-band. Thus, the FOREST uses eight 2SB mixers and has 16 intermediate frequency (IF) outputs in total. A configuration of 4 beams is a quadrate of 2×2, and a separation of 2 adjacent beams is designed to be $\sim 50\,''$. IF bands are set to 4.0 – 8.0 GHz in the lower sideband (LSB), but set to 4.0 – 12.0 GHz in the upper sideband (USB) in order to observe $C^{18}O(J = 1 - 0)$ line at 109.78 GHz, $^{13}CO(J = 1 - 0)$ line at 110.20 GHz, and $^{12}CO(J = 1 - 0)$ line at 115.27 GHz simultaneously.

We installed the FOREST on the 45-m telescope in 2012 March, and started test observations from the next month. The tentative receiver noise temperatures were 70 – 200 K in single sideband, and the image rejection ratios (IRRs) were typically 5 – 10 dB at the radio frequency of 110 GHz. First, we determine the optimum position of the sub-reflector for the FOREST by observing continuum emission of the Saturn. Secondary, we obtain the beam pattern of the antenna for each beam by observing the SiO maser at 86 GHz in LSB. The measured beam separation is $51''.7$, which is consistent with the optics design, and we found no major deformation of the beam pattern. Thus, we judged that the mapping with the FOREST can be performed without any incident. Finally, we successfully obtained $7' \times 7'$ on-the-fly maps in $C^{18}O(J = 1 - 0)$, $^{13}CO(J = 1 - 0)$, and $^{12}CO(J = 1 - 0)$ line emission of the standard source, W 51, simultaneously with all the 4 beams.

Through the test observation, we got an important foothold in the scientific observing run of the FOREST from 2013 although we have to solve remaining problems as follows: (1) performance upgrade of 2SB mixers (receiver noise temperature, IRR, etc.), (2) improvement of band characteristics in USB, and (3) construction of a rapid receiver tuning system.



Appearance and alignment of components of the FOREST designed with 3 dimension CAD platform.

The Greenland Telescope (GLT) Project
— For submm VLBI and THz astronomy —

M. INOUE[1], K. ASADA[2], S. MATSUSHITA[3], AND THE GLT TEAM[4,5,6,7]

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[5] Smithsonian Astrophysical Observatory, USA. [6] MIT Haystack Observatory, USA. [7] NRAO, USA.

Using an ALMA prototype antenna, we have been deploying a submm and THz observing telescope at the summit on the Greenland ice cap. The primary target of this Greenland Telescope (GLT) is to identify a shadow image of Super Massive Black Hole (SMBH) with Very Long Baseline Interferometry (VLBI). The site selection was done based on the following criteria: (1) to produce longer baselines with existing and planned submm telescopes, and (2) to have high sky transparency at submm and higher frequencies.

The GLT gives longer baselines with the existing submm telescopes. In particular, the summit is 3,200 m high and temperature goes down to -70°C. Together with ALMA in Chile and SMA in Hawaii, the GLT forms an excellent triangle to observe M87, one of the most promising targets to figure out the shadow image. Phase-up ALMA will give high sensitivity to the triangle, performing a key triangle at 345 GHz with the angular resolution of 20 μ arcsec. As the GLT produces longer North-South baselines, it also provides a great opportunity to investigate the prominent jet of M87.

By the radiometer monitoring at 225 GHz, the summit site is shown as one of the best sites for submm and THz observations on the Earth. For one year monitoring of the opacity, the sky opacity is shown to be comparable to that of ALMA and the South Pole Telescope, as seen in Figure 1. The single dish operation is planed as the observation time for VLBI is not dominant. We are planning to install single dish instruments like bolometer arrays and multi feed heterodyne receivers.

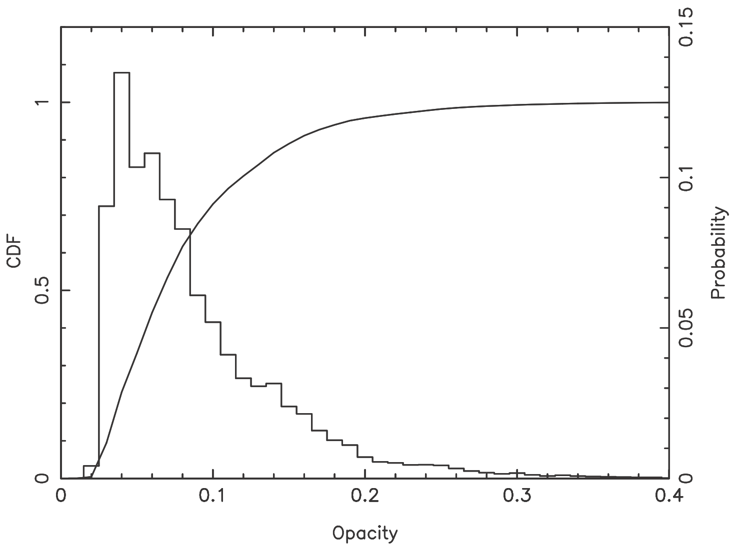

Figure 1. Histogram (right axis) and Cumulative Distribution Function (left axis) of the opacity monitored at the summit of the ice cap on Greenland. We set a tipping radiometer at 225 GHz in August 2011 at the roof of a polar research facility to monitor the opacity. The plotted data are from 17 Aug. 2011 to 13 May 2012, and the quartiles are 0.05, 0.08 and 0.11 for 25, 50 and 75%, respectively.

The antenna has been retrofitted for the cold environment on Greenland, and it is planned to be set up at the summit in 2015. During summer, an air cargo is transporting materials once every week, and every three months in winter.

The overall profile of this GLT project will be presented by K. Asada in this meeting, and here we will give the GLT project a little more in detail.

P101

The 0.9 and 1.3 THz Superconducting HEB Mixer Receiver for the ASTE 10 m Telescope

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In the THz region, there exist many spectral lines of various fundamental atoms, ions and molecules, which give us novel information on chemical and physical state of interstellar clouds including star and planet forming regions. Although observations of these lines have successfully been done with Herschel HIFI, further observations with higher angular resolution from the ground-based telescope are still important for some THz atmospheric windows. With this in mind, we have been developing superconducting HEB (Hot Electron Bolometer) mixers for the THz frequency region at The University of Tokyo. By use of these mixers, we have prepared a cartridge-type THz heterodyne receiver for the 0.9 THz and 1.3-1.5 THz bands, and have successfully conducted a commissioning run in 2011 on the ASTE 10 m telescope (Atacama Chile).

The receiver is the ALMA cartridge type with a single beam. It can observe the dual bands (0.9 THz and 1.3-1.5 THz) simultaneously in the DSB mode by using the wire grid. The IF band is 1.0-1.2 GHz. As for local oscillators (LOs), we use 3 different multiplier chains driven by a microwave synthesizer for the 3 observation frequencies; 0.9, 1.3, 1.5 THz. In the commissioning run, the LOs for 0.9 and 1.3 THz have been installed. We employ the in-house waveguide HEB mixers for the both bands. Although SIS mixers now show a better performance than HEB mixers at 0.9 THz, we use the HEB mixer to demonstrate observation capability of our HEB mixer. We use NbTiN superconducting films fabricated on a quartz substrate for the HEB mixers. The thickness of superconducting microbridges is 10.8 nm. The receiver performance is measured in the test cryostat, and the minimum receiver noise temperatures achieved are as low as 390 K for the 0.8 THz, 490 K for the 1.5 THz mixers.

The lowest system noise temperature including atmospheric attenuation is around 1000 K at 880 GHz, when the precipitable water vapor is 0.18 mm. From the continuum observation of Jupiter, the beam efficiency is derived to be about 30% at 880 GHz for the illumination of the inner 7 m area of the 10 m telescope. Furthermore, we have succeeded in detecting the spectral line of ^{13}CO ($J = 8 - 7$; 881.3 GHz) toward the Orion A molecular cloud. In addition to this, we will report the results of the 2nd commissioning run in 2012.

P102

Development of Wideband Feed and Receiver System for Kashima 34m Antenna

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Wide band feed and reciver system for Kashima 34m antenna has been developing in NICT. This system uses 4ch, in 3.2-13.8GHz, which are 3.2-4.2GHz, 4.8-5.8GHz, 9.6-10.6GHz, and 12.8-13.8GHz, because of RFI and minimum redundancy in frequency space. It is aimed for precious time transfer by geodetic VLBI technique and for VLBI 2010, also will be a good milestone in a way to future wideband radio telescope system such as SKA. The Author, at first planed the feed by a kind of arrayed TWA(Traveling Wave Antenna)[1], however, we must have developed the feed in 2012 for the operation of time transfer. Thus. the Author decided using a multimode horn within a corrugated horn for the project. This is complicated but easier way than controlling beam width of arrayed TWA. Figure 1 shows the image of the feed and figure 2 shows reciever system block diagram. Conventional down-converter system will be used in the first step, however, it will be evolved into direct sampling system.

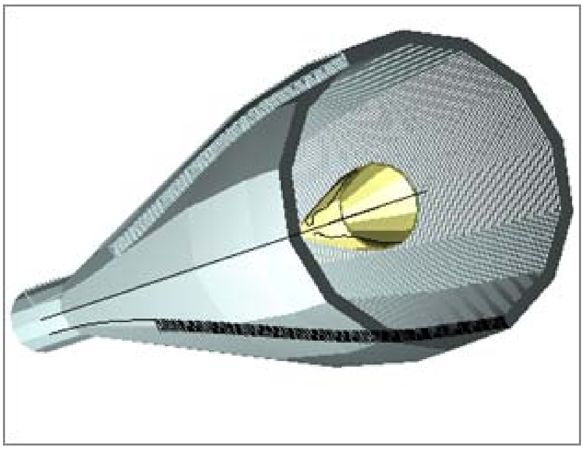

Figure 1: 3D CAD model of feed

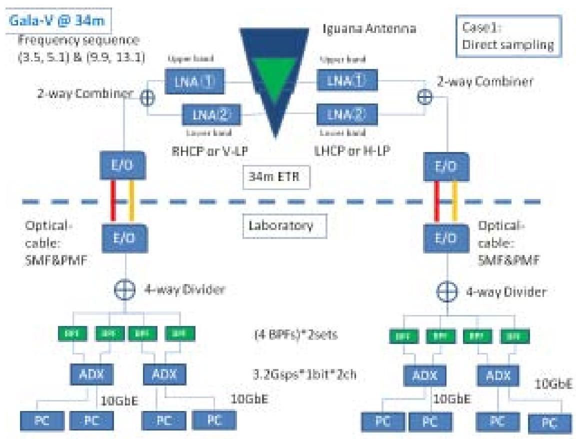

Figure 2: receiver system for 34m antenna.

This system was named "Gala-V" which means "Galapagos VLBI". The feed horns are called Iguana-Mam and Daugter feed. Ofcourse it was named after "GALA-KEE" which is a domestic cellar phone systems in JAPAN, like the evolution in Galapagos island. The authors selected best frequencies for operation in Kashima, however, the system will be adopted and evolved to fit another location in the world. Becasue our site is seemed to be one of the world highest RFI site.

[1] "Delopement of mutimode horns and wideband feed for radio telescopes"
H. UJIHARA, K. KIMURA, K. MATSUMOTO, H. OGAWA, T. OHNO, M. TSUBOI, T.KASUGA, M. HOMMA and N. KAWAGUCHI,
General Assembly and Scientific Symposium, 2011 XXXth URSI $(13 - 20Aug.2011)$

P103

The 1.85m mm-submm telescope: A newly-developed CO multi-line surveyor

A. Nishimura[1*], K. Kimura[1], K. Muraoka[1], H. Maezawa[1], T. Onishi[1], H. Ogawa[1], K. Dobashi[2], and 1.85m Group

[1] Osaka Prefecture University, Japan., [2] Tokyo Gakugei University, Japan.

*

We have developed the 1.85m mm-submm telescope to improve our understandings of the physical conditions (e.g., temperature, density) of molecular clouds in the Galaxy for bridging the gap in understanding between molecular clouds evolution and star formation therein. The telescope is installed at Nobeyama (Fig.1). We installed a receiver system equipped with 2-SB mixers, which enable us to achieve simultaneous observations of the molecular rotational lines of J=2–1 of carbon monoxide and of the isotopes (^{12}CO, ^{13}CO, and C^{18}O) at 230GHz band. The 2'.7 beam size of the telescope is suitable to obtain a large scale distribution of molecular gas which also can be compared with large-scale observation data in various wavelengths e.g., with Planck, Herschel, Spitzer, Fermi, and so on. In addition, the large scale molecular dataset toward the Galaxy is of intrinsic importance for comparing with giant molecular clouds (GMCs) properties of the external galaxies; we just start resolving spatially the GMCs in the external galaxies with large aperture telescopes in the ALMA era.

We started the project in 2006, and the telescope was move to Nobeyama at the end of 2007. After various commissioning activities, we have successfully started the science observations since January 2011. Our first observing targets include famous star forming molecular clouds covering a variety of star formation environments (Table1). The observation coverage is a few hundred square degrees in total in the first 2 years. From these observations, we found that the observations in ^{13}CO(J=2–1) is quite important to derive precise physical properties. Because of the high critical density for the excitation, the intensity is very sensitive to the density for molecular clouds with a density of $\sim 10^3$cm^{-3} although the ^{13}CO(J=1–0) can trace gas with much lower densities. Furthermore because the ^{13}CO lines tend to be optically thin toward most of the clouds, the line ratios (2–1/1–0) are also very sensitive to the temperature of around 10K. For instance, the distribution of ^{13}CO(J=2–1)/^{13}CO(J=1–0) ratios in the Orion data has a steep gradient around the HII region, ranging from 0 up to $\sim$2 (Fig.2). This change reflects the large fluctuations of the densities and temperatures around the HII region. The ^{13}CO(J=2–1)/^{12}CO(J=2–1) ratio is considered to reflect the local density of around 10^3cm^{-3} due to the high critical density and to the effect of the photon trapping of the ^{12}CO(J=2–1) line. From these reasons, we conclude that the combination of line ratios of ^{13}CO(J=2–1)/^{13}CO(J=1–0) and ^{13}CO(J=2–1)/^{12}CO(J=2–1) is a very powerful tool for the determination of physical properties of molecular clouds (Nishimura et al. 2012 in preparation). The natural extension of this fact is that the combination of two optically thin lines with different transitions and one optically thick line (e.g., ^{13}CO(J=1–0), ^{13}CO(J=3–2), and ^{12}CO(J=3–2)) can be used for the precise derivation of the physical properties of star forming molecular clouds.

Table 1: Observation summary

Name	Map size	Note
Orion	55 deg^2	Massive star formation
CygnusX	43 deg^2	Massive star formation
CygnusOB7	96 deg^2	No star formation
Taurus	42 deg^2	Low mass star formation
Galactic Plane	18 deg^2	

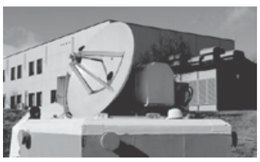

Fig 1: A photo of the telescope.

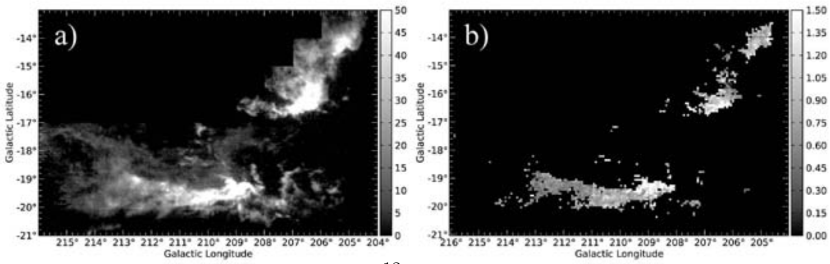

Fig 2: a) Integrated intensity map of the ^{12}CO(J=2–1) emission in the Orion molecular cloud observed by the 1.85m telescope. b) Line ratio map of ^{13}CO(J=2–1)/^{13}CO(J=1–0). J=1–0 data were observed in Nagahama et al. 1998.

P104

Photon Counting Terahertz Interferometry for Exo-Planet Imagings

H. MATSUO

Advanced Technology Center, National Astronomical Observatory of Japan.

Terehertz frequency region is a frontier of radio astronomy, which is overlapped with far-infrared wavelength. In this frequency region, radio technology and photon technology both can work. In this presentation, I will discuss on a new interferometer technology that uses the combined technology of photons and waves.

We are proposing Photon Counting Terahertz Interferometry (PCTI) for future instrumentation, which is based on an intensity interferometry demonstrated by Hanbury-Brown and Twiss (1956), but using photon counting detectors in terahertz frequencies. Photons follow Bose-Einstein statistics, so coherent behavior of photons such as photon bunching is observed, which is a source of noise for direct detectors. But, this photon bunching is important for intensity interferometry to be effective. In optical wavelengths, photon bunching is less and photon bunching is observed when the source brightness temperature is more than 10^5 K.

In terahertz frequencies, the brightness temperature of 100 K is enough to observe the photon bunching, because the photon energy is much lower. Also, if we count all the photon arrivals, we can, in principle, identify arrivals of photon bunches, such as mean arrival times of bunched photons. When corresponding photon bunches are identified from two separate telescopes, the time tagging of photon bunches can be used to measure the delay of photon arrivals, hence, phase information can be obtained.

The practical photon arrival time for astronomical observation is estimated to be 1-100 MHz. This can be met by fast photon counting detectors in infrared wavelength, but not yet feasible in terahertz frequencies. There are a number of detector technologies which can bed applied to realize this, such as superconducting tunnel junction detectors, superconducting single photon detectors and semiconductor detectors.

Observing target in terahertz frequency region is compact sources with brightness temperature higher than about 100 K. One example is far-infrared atomic fine-structure lines, such as [CII], [NII], [OIII], from starforming regions. Another example is exo-planet searches, which requires very high angular resolutions. The highest angular resolution by PCTI can be achieved by VLBI like system. High timing accuracy for VLBI can be used together with the photon counting detectors to measure delay of photon bunches. When baseline larger than 1000 km is realized at 2 THz, you can start to resolve exo-planets, earth-like planets around nearby stars.

Although this is a case study of a future interferometer technology, fast and high dynamic range detectors for interferometry will open new frontier of terahertz astronomy and astrophysics.

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