Half a Decade of ALMA:
Cosmic Dawns Transformed

Poster Abstracts

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Physical Conditions in the Nuclear Region of Merging Starburst Galaxy NGC 1614

The interaction between gas-rich galaxies plays a fundamental role in the evolution of galaxies. This process triggers starburst and merging galaxies often become bright in IR luminosities. Since the role of the molecular gas in this mechanism is crucial, quantifying the physical condition of ISM is important for understanding mergers and galaxy evolution. Here we present high resolution ($\sim$ 1": $\sim$310 pc) Atacama Large Millimeter/submillimeter Array (ALMA) line data of ^{12}CO(J=1-0, 2-1) and ^{13}CO(J=1-0, 2-1) in NGC 1614, which is a local luminous infrared galaxy and thought to be a late-stage merger. The differences in the distribution of these lines come from the differences in the excitation conditions and/or relative abundance ratio. By solving radiative transfer equation under the assumption of large velocity dispersion condition, we estimate the physical condition, such as kinetic temperature, H_2 number density and column density of each molecule, at several regions within the galaxy. We find that the molecular gas is cold ($\sim$ 40 K) and dense ($> 10^3$ cm^{-3}) around the starburst ring, and becomes more diffuse at the outer regions. In addition, it is known that the ratio of low-J ^{12}CO/^{13}CO lines in luminous mergers is higher than normal spiral galaxies. We show the ^{12}CO/^{13}CO(J=1-0, 2-1) ratio maps and suggest an interpretation of their relation to interaction events.

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About the Detection of Faint Sources in ALMA Deep Fields

Spurious detection of faint sources in interferometric maps may lead to significant overestimate of their number counts and have severe consequences for determining their statistical properties (as the luminosity function and its evolution).

When the position and number of the point sources in a map are unknown, the commonly-adopted source detection algorithms, like the matched filters, may severely underestimate the probability of false detection. As a consequence, statistical significance is given to structures that are actually due to the noise.

We propose a method which is able to provide a correct estimate of the probability of false detection when the noise although Gaussian is not white.

We have applied this method to a few ALMA maps and have shown how to distinguish real sources from blob-shaped structures due to noise, and have detected several sources with high statistical significance.

Adam Avison (UK ALMA Regional Centre Jodrell Bank Centre for Astrophysics)

Ian Heywood

The ALMA Observation Support Tool: The First Five Years

The ALMA Observation Support Tool is an online ALMA simulator aimed at the non-interferometry expert and has been available to the astronomical community since the start of the ALMA Cycle 0 call for proposals in 2011.

Users interact with the OST by filling in and submitting an online webform. Simulations are then processed in Manchester UK, at the UK ALMA Regional Centre Node. On completion of the simulation the OST then emails the user a link to a webpage featuring their simulation results which are available for download.

Since coming online the OST has processed over 15,000 ALMA simulations. We present an overview of the OST, chart its evolution and international usage over the half a decade it has been available and describe the OSTś potential future developments.

Ashley Bemis (McMaster University)

Christine Wilson (McMaster University)
Maximilien Schirm (McMaster University)

Investigating Dense Gas and Star Formation in the Antennae Galaxies (NGC 4038/39) using ALMA

The Antennae is the nearest pair (22 Mpc) of interacting galaxies and shows evidence of recent, wide-spread star formation. Using CPROPS, we produce dense gas cloud catalogues for HCN, HCO+, and HNC for a cloud-by-cloud analysis of different regions, including the two nuclei, overlap, and western arm. We study the relationship between dense gas and star formation in the Antennae by comparing ALMA observations of dense gas tracers (HCN, HCO+, and HNC) to 70 micron data from the Herschel Space Observatory. We use OVRO CO data to calculate star formation efficiencies and dense gas mass fractions for these different regions. Upper limits of dense gas emission are derived for the brightest star-forming regions where emission was expected but not detected. We confirm the results from Bigiel et al. (2015), which compares CARMA data of these dense gas tracers in the brightest regions of the overlap region and two nuclei, and extend this analysis to fainter regions of emission.

George Bendo (University of Manchester)

Measuring Star Formation Rates in Nearby Dusty Starburst Galaxies Using ALMA Observations of Millimeter Recombination Line and Free-Free Emission

ALMA can directly measure both millimeter recombination line emission and free-free continuum emission from star forming regions in nearby galaxies. As this emission directly traces the photoionizing light from young stellar populations while not being affected by dust attenuation effects, it can be used to calculate very accurate star formation rates (SFRs). We present the first results from using ALMA to measure this line and continuum emission within multiple nearby galaxies, including the very dusty starbursts at the centers of NGC 253 and NGC 4945. A comparison of the SFRs from the ALMA data to SFRs from other wavebands, particularly infrared and longer-wavelength radio data, illustrate some of the potential issues with the other star formation tracers, including the surprising result that dust obscuration may be so high in starburst galaxies that SFRs from mid-infrared data will be biased to very low values.

Per Bjerkeli (Niels Bohr Institute Copenhagen University)

J K Jörgensen (Niels Bohr Institute)

Water Released in a Protostellar Accretion Burst

When dust temperatures close to protostars increase above 100 K, water quickly sublimate from the grains. The location of this s̈now line ḧas critical effects on disk chemistry and ultimately also on the composition of forming planets. Previous ALMA observations towards IRAS15398, of an indirect tracer of the snow line (HCO+), has revealed that the extent of the 100 K region in the past has been significantly larger than what is expected from its current luminosity. A possible explanation to this is that the protostar recently went though a burst in accretion. A burst occurring 100 - 1000 years ago, is also hinted by dynamical events in the CO(2-1) outflow maps obtained with the Sub-Millimeter Array.

Here, we present high-resolution ALMA observations of warm water towards the IRAS15398 system. We observed the emission from two isotopologues, viz. HDO(101-000) at 465 GHz and H218O(414-321) at 390 GHz. HDO is detected towards the protostar and in the outflowing gas at distances up to 500 AU from the protostar. H218O is, on the other hand, not detected in the imaged region. The non-detection of H218O, and the detection of HDO, is consistent with a post-burst scenario where current envelope temperatures are low. The two lines have very different excitation temperatures (22 K for HDO and 322 K for H218O) and we thus not expect H218O to be highly excited in these environments. Even though temperatures likely are low, HDO is also detected in the outflow component at larger distances from IRAS15398. The presence of water on these scales can, however, not easily be explained by outflow chemistry. To calculate the dust radiative transfer, we use the code RADMC-3D. We conclude that the presence of an outflow, where the density is lower than in the surrounding envelope, can have profound influence on the dust temperature distribution, and therefore also the location of snow-lines. In the case of IRAS15398, the 100 K distance in the outflow is likely larger than 500 AU, when the protostar undergoes a burst. In addition to the water observations, we also present detailed maps of other species, e.g. CS(8-7) and N2H+(5-4). These emission maps reveal signs of a rotating protostellar disk and the detailed kinematics and morphological structure of the outflowing gas.

Per Bjerkeli (Centre for Star and Planet Formation Niels Bohr Institute Natural H)

Matthijs van der Wiel (Centre for Star and Planet Formation Niels Bohr Institute Natural H)
Daniel Harsono (Heidelberg University Center for Astronomy Institute of Theoretical)
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Resolving the Outflow Launching Region With ALMA

The most striking manifestation of the star formation process are molecular outflows which efficiently remove angular momentum from protostellar systems. Outflows also permit inward accretion and the continued growth of stars.

Limits to the angular resolution of observations, however, have meant that, to date, outflow launching regions are only probed indirectly. The ejection mechanism is believed to be closely related to the protostellar disk, but the most promising theories have difficulties explaining some of the observed features on large scales. The main difference between these models is where the acceleration of material takes place: close to the protostar itself (X-wind or stellar wind) or throughout larger radii of the disk (disk wind). The underlying mechanism for outflow ejection has been debated in the community for decades.

Here, we present observations of a young protostellar system at an unprecedented spatial resolution, taken with ALMA. The dataset allow us to discriminate between different launching scenarios and it also advances our understanding of how material can be redistributed close to the central protostar.

Eva Bogelund (Leiden Observatory)

Michiel Hogerheijde (Leiden Observatory)

Exploring the volatile composition of comets C/2012 F6 (Lemmon) and C/2012 S1 (ISON) through ALMA

We re-analyse archival observations obtained with the Atacama Large Millimetre/Submillimetre Array (ALMA) of the volatile composition of the comae of comets C/2012 F6 (Lemmon) and C/2012 S1 (ISON). We confirm the detection of hydrogen cyanide, HCN, its metastable isomer hydrogen isocyanide, HNC, and formaldehyde, H2CO, as reported by Cordinet et al. (2014), and in addition report on the detection of carbon monosulfide, CS, as well as several methanol, CH3OH, transitions. We map the spatial distribution of each molecule and find centrally peaked, symmetric distributions for CS, HCN and CH3OH, indicative of parent species, i.e., species sublimated directly from the cometary nucleus. In contrast we see distributed origins for HNC and H2CO consistent with these species being either the result of gas-phase chemistry in the coma or transported away from the nucleus by some refractory compound before being evaporated.

Using the 3D radiative transfer code LIME (Brinch & Hogerheijde 2009), and assuming a Haser profile with constant outflow velocity, we model the line intensity of each transition and derive molecular production rates. In addition, we explore how the observations of multiple transitions of the same molecule can improve the accuracy of our derived production rates and help constrain the coma temperature.

Benjamin Boizelle (UC Irvine)

Aaron Barth (UC Irvine)
Jonelle Walsh (Texas A&M)
Andrew Baker (Rutgers)
Jeremy Darling (Colorado)
Luis Ho (Kavli Institute)

Circumnuclear Disks in Early Type Galaxies: 12CO(2-1) and Continuum Properties

We present results from an ALMA Cycle 2 program designed to map the circumnuclear CO(2-1) emission in early-type galaxies (ETGs) and measure black hole masses. A substantial fraction of nearby ETGs possess round, morphologically regular nuclear dust disks. The accompanying molecular gas is expected to be in uniform, circular rotation and therefore be a good dynamical tracer of the inner galaxy potential. We obtained 0.3"-resolution observations of seven ETGs which were selected based on the presence of nuclear dust disks seen in HST images. For the five detected in CO(2-1), we find that these molecular gas disks are in dynamically cold rotation, and four of these show clear evidence of rapid central rotation. We present the gas distributions and kinematics of these molecular disks, as well as the continuum properties of the dusty disks and the prevalence of low-luminosity active galactic nuclei at their centers. We also discuss the suitability of molecular gas disks in ETGs for making precision measurements of black hole masses. For one of our galaxies, we have already measured its black hole mass with a precision of 10%.

Frederic Boone (IRAP Toulouse)

Daniel Schaerer (Geneva)
Eiichi Egami (Tucson)
Johan Richard (Lyon)
Benjamin Clement (Lyon)
Gregory Walth (Tucson)

ALMA Mapping of Lensing Clusters with Herschel Dropouts

We observed with ALMA four clusters of the Herschel Lensing Survey(HLS) followed up at 870 μm with LABOCA. Preliminary results from the analysis of the mosaics are presented. The nature of the Herschel dropouts detected with LABOCA in these clusters is discussed.

Drew Brisbin (Universidad Diego Portales)

Manuel Aravena
Vernesa Smolcic
Ivan Delvecchio
Oskari Miettinen
Alex Karim

Submillimeter Galaxies in the COSMOS Field: Multiwavelength Counterparts and Redshift Distribution

We carried out targeted observations of 129 fields in the COSMOS region at 1.25 mm, detecting 152 galaxies at S/N¿5 with an average continuum RMS of 150 μJy. These fields represent a S/N-limited sample of AzTEC /ASTE sources with 1.1 mm S/N$\geq$4. Given ALMAś fine resolution and the exceptional spectroscopic and multiwavelength photometric data available in COSMOS, this survey allows us unprecedented power in identifying submillimeter galaxy counterparts and determining their redshifts through spectroscopic or photometric means. In addition to many sources with prior spectroscopic redshifts, we have identified redshifts for 117 galaxies through photometric methods, allowing a statistically robust determination of the redshift distribution. Our z distribution peaks at z$\sim$2.2, generally consistent with previous submillimeter galaxy surveys after accounting for spectral energy distribution shape and selection effects.

Nathan Brunetti (McMaster University)

Christine D Wilson (McMaster University)

An ALMA Archival Study of the Clump Mass Function in the LMC

I present preliminary results of an ALMA archival study that combines data from several separate projects to build a large sample of clouds and cores in the Large Magellanic Cloud (LMC). These projects contain continuum and spectral line data of 30 Doradus and N159W over a combined area of 7 square arcminutes in Bands 3 and 6 (95 and 228 GHz respectively). I focus on using the continuum data to estimate dust masses for these sources as well as an analysis of the cloud/clump properties to construct a molecular gas clump mass function (CMF). The lower metallicity in the LMC will be used in comparison with galactic studies to explore the effects of metallicity on the CMF. I will also discuss the wider continuum and eventually spectral line archival studies that will be enabled by this data gathering approach. Further objects I plan to include that are available through the ALMA archive are N166 and GMC 225 as well as potentially several Small Magellanic Cloud and Magellanic Bridge objects with the goal to build a data set with substantially improved statistics compared to any single ALMA project. Currently, the rate limiting step for adding fields is waiting for data in both bands with at least 12m observations to become publicly available.

Andrew Burkhardt (University of Virginia)

Christopher Shingledecker (University of Virginia)
Brett McGuire (National Radio Astronomy Observatory)
Niklaus Dollhopf (University of Virginia)
Anthony Remijan (National Radio Astronomy Observatory)
Eric Herbst (University of Virginia)

Modeling the After-Effects of Shocks Toward L1157

Shocks have been found to be ubiquitous throughout the interstellar medium and in star forming regions. How these phenomena affect the chemistry, especially the interplay between gas-phase and grain-surface processes, in these regions has yet to be fully understood. In the prototypical shocked-outflow of L1157, we can study the effects that recent shocks ($\sim 10^3$-10^4 years ago) can have on previously cold, quiescent gas, where many of the complex molecules are thought to be locked within grains. Toward a single shock event, C2, a significant chemical differentiation is observed between the previously shocked gas along the eastern wall and the newly shocked gas along the western wall. In addition, substantial enhancement of HNCO towards the younger shock, C1, may imply high-temperature O-chemistry is important soon after the passage of a shock. Here, we utilize the gas-grain chemical network model NAUTILUS, along with the inclusion of high-temperature network and shock-physics parameters, in order to investigate the prominence of these effects.

Vivien Chen (National Tsing Hua University Taiwan)

Fumitaka Nakamura (NAOJ)
Qizhou Zhang (Harvard-Smithsonian CfA)
Gemma Busquet (CSIC-IEEC Spain)
Satoshi Ohashi (The University of Tokyo Japan)
Ken Tatematsu (NAOJ)

Filamentary Accretion Flows in the IRDC M17 SWex

Although filamentary structures are ubiquitous in molecular clouds, basic observational constraints are needed to clarify the role of filaments in the mass assembling process. Using ALMA Band 3, we have observed the N_2H^+ and HNC emission in the filamentary accretion flows in the remarkable IRDC complexes, M17 SWex, where a delayed onset of massive star formation was reported in the two hubs at the convergence of multiple filaments of parsec length. We derived gas kinematics with the N_2H^+ emission and found the line widths are smaller than those of ammonia, suggesting a transonic nature of dense gas in the filaments. Slow infall motions towards the hubs are detected along the filaments. Multiple velocity coherent substructures are present in both hubs, likely not yet reaching virial equilibrium.

Pou-Ieng Cheong (Institute of Astronomy National Tsing Hua University)

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Shih-Ping Lai (Institute of Astronomy National Tsing Hua University)
Tao-Chung Ching (Institute of Astronomy National Tsing Hua University)
Nadia Murillo (Max-Planck-Institut für extraterrestrische Physik MPI)

ALMA Observations of Spiral Accretion Flows Towards Extremely Young Protostars

Studying the accretion flows toward extremely young protostars is an important step for understanding how the protostars are assembled in the early stage of star formation. The accretion flows are commonly seen in the MHD numerical simulations; however, it is rarely observed toward young protostars. Here we investigate the accretion flows in an extremely young protostar VLA1623A with a protostellar disk likely just formed. With the largest submillimeter telescope in the world, Atacama Large Millimeter/submillimeter Telescope (ALMA), we discover 5000 AU long accretion flows toward VLA1623 in $C^{18}O$ emission. D̈endrogram älgorithm are used to identify the accretion flows, and we find the three brightest b̈ranches änd their associated l̈eaves l̈ikely correspond to the spiral structure flowing toward the central young cluster (Figure 1, Right). The fourth brightest branch may correspond to an outflow associated with VLA1623W. We further compare the PV diagrams of the three accretion flows to the CMU model which describe the velocity structure of the gas accreting to the central protostar with constant angular momentum, and we find that our identified branch structures well match with the CMU model.

James Chibueze (National Astronomical Observatory of Japan)

Timea Csengeri (MPIfR)
Kazuhito Motogi (NAOJ)

G357.97-0.16 - ALMA and KaVA View of a High-mass Protostar

Band 7 ALMA observations of G357.97−0.16 unveil its millimeter properties. The mm continuum core is associated with 6.7 GHz methanol (CH_3OH) maser indicating the presence of a high-mass protostar. We have compared the results from ALMA with (KVN and VERA combined) multi-epoch VLBI observations of the target source at 22 GHz (water, H_2O maser). The maser proper motions trace compact outflows around the driving source, while the kinematic structures seen in the ALMA molecular line provide clues into the nature of driving source.

Se-Hyung Cho (Korea Astronomy and Space Science Institute)

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Kee-Tae Kim (KASI)
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Two New SiO Maser Sources in High-Mass Star-Forming Regions

We present the ALMA Cycle 2 results T̈wo New SiO Maser Sources in High-Mass Star-Forming Regionsẅhich was published in the astrophysical journal 826, 157, 2016. Silicon monoxide (SiO) masers are rare in star forming regions, with the exception of five known SiO maser sources. However, we detected two new SiO maser sources from infrared loud clumps of the high-mass star forming regions G19.61-0.23 and G75.78+0.34. High angular resolution observations toward G19.61-0.23 suggest that the deeply embedded young stellar object (YSO) of SMA 1 is powering the SiO masers. In addition, the SiO v=1, J=1-0 line shows four spike features while the v=2 maser shows combined features of one spike and broad wing components, implying energetic activities of the YSO of SMA 1 in the G19.61-0.23 hot molecular core. The SiO v=0, J=2-1 emission shows bipolar outflows in NE-SW direction with respect to the center of the SiO maser source. A high angular resolution map of the SiO v=1, J=2-1 maser in G75.78+0.34 shows that the SiO maser is associated with the CORE source at the earliest stage of high-mass star formation. Therefore, the newly detected SiO masers and their associated outflows will provide good probes for investigating this early high-mass star formation.

Aeree Chung (Yonsei University)

Daisuke Iono (NAOJ)
Min S Yun (UMass)

Molecular Gas Properties of HI Monsters

The cold gas reservoir surrounding present day massive galaxies like the Milky Way is generally insufficient to maintain the current star formation rate or to explain their baryonic mass assembly history, and additional mass accretion mechanism such as a cold flow is necessary to account for the observed properties. This problem becomes more severe in the earlier epochs at z 1 when the average star formation rate and gas mass fraction for such galaxies are thought to be much higher. We have identified a large sample of local analogs with a large cold gas reservoir, dubbed HI monsters, in order to investigate the path(s) and efficiency of the conversion of the neutral atomic reservoir into molecular form, which ultimately fuels their present star formation activities. These objects also represent special laboratories for investigating process of building a massive cold gas reserve from its environment. In this work, we present the molecular gas morphology and kinematics of 10 HI monsters based on the ALMA 12CO (1-0) observations, and discuss their implications for galaxy growth.

Yanett Contreras (Leiden University)

Yanett Contreras (Leiden University)

Initial Conditions of Cluster Formation

Recent observations of Galactic plane surveys have allowed us to determine the physical global properties of proto cluster candidates, making possible the selection of the best candidates of clumps in the verge of star formation, for follow up observation of their small-scale structure with ALMA. Here we present recent ALMA observations toward the cold molecular clump G331.3-00.1. This clump satisfies all the requirements (cold, dense and high-mass) for a cluster-forming clump in a very early stage. Our ALMA observations have allowed us to measure its internal structure to assess whether the cores located in this clump are gravitationally bound and collapsing. Moreover, its location in the benign environment of the solar neighbourhood allows us to directly compare its properties to other clumps located in extreme environment, such as the Brick located in the Central Molecular Zone.

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Finding Weak Phase Calibrators for ALMA Targets

With ALMAś impressive sensitivity, relatively weak calibrators can be used for phase referencing observations of scientific targets, and two methods are now used to find suitable calibrators. First, for the high frequency proposals (HF: ¿400 GHz), all known phase calibrator candidates located within 10 degrees of all cycle 3 HF target sources were observed. The observations were carried out for each candidate, switching between bands 3 and 7 (LF: 100 and 280 GHz) so that their flux density at higher frequencies could be estimated. During periods of dry weather, switching observations in bands 7 (350 GHz) and 9 (650 GHz) were made, and these confirmed that extrapolation from LF to HF was accurate to 25observations are suitable for finding HF calibrators. The flux densities of 400 sources were measured over the last six months, significantly increasing the flux information of the weaker sources in the ALMA catalog. Sources as weak as 200 mJy at band 9 can be used as ALMA phase calibrators.

Secondly, during slack periods of available PI observations, candidate phase calibrators were observed at 100 and 280 GHz. The ALMA calibrator list of over 10000 potential candidates around the sky, compiled mostly from the AT20G and VLA calibrator catalogs, was searched and candidates without recent measurements which were likely to be stronger than 15 mJy at band 3 were selected. An automatic observing script selected sources within 15 deg of a suitable ALMA strong phase. The data analysis generally used baselines less than 1.5 km and WVR and TSYS corrections (which supplied sufficient bandpass calibration) were applied. If the source used for phase referencing was monitored regularly as a flux standard, this was used to set the flux scale. Otherwise, the system temperature was used. Phase self-cal was applied if necessary, and the flux density of the candidate was measured from cleaned images. The image residuals and amplitude-uv distance plots were used to check the data quality and to identify multiple and extended sources. These diagnostics, along with the flux density statistics (peak and integrated), were used to evaluate the suitability of the candidate. The majority of the candidates have accurate positions already measured by VLBI at cm wavelengths, and only a few percent were found to be offset at the 100 mas or more or contained a resolved candidate. Sources with positions less accurate than 0.03c̈an be improved with additional ALMA observations.

Paulo Cortes (NRAO JAO)

The ALMA View of the Magnetic Field in W43-MM1

Here we present the first results from ALMA observations of 1 mm polarized dust emission towards the W43-MM1 high mass star forming clump. We have detected a highly fragmented filament with source masses ranging from 14Msun to 312Msun, where the largest fragment, source A, is believed to be one of the most massive in our Galaxy. We found a smooth, ordered, and detailed polarization pattern throughout the filament which we used to derived magnetic field morphologies and strengths for 12 out of the 15 fragments detected ranging from 0.2 to 9 mG. The dynamical equilibrium of each fragment was evaluated finding that all the fragments are in a super-critical state which is consistent with previously detected infalling motions towards W43-MM1. Moreover, there are indications suggesting that the field is being dragged by gravity as the whole filament is collapsing.

Tanio Diaz-Santos (Universidad Diego Portales Chile)

Roberto J Assef (Universidad Diego Portales)
Andrew Blain (University of Leicester)
Chao-Wei Tsai (JPL)
Manuel Aravena (Universidad Diego Portales)
Peter Eisendhart (JPL)

ALMA Reveals the Turbulent Life of the Most Luminous Galaxy in the Universe

In this talk I will present results of spatially resolved ALMA [C II]157.7m observations of WISE 22460526, the most luminous galaxy known in the Universe. WISE 22460526 is located at a redshift z 4.6 only 1.3 Gyr after the Big Bang and hosts a super-massive black hole (SMBH) at its center. We find a strikingly uniform, 600 km/s wide line emission across the entire galaxy on several kpc scales, a combination of properties not observed before in any other high redshift source. Such a large, homogeneous velocity dispersion indicates a highly turbulent interstellar medium (ISM). WISE 22460526 is unstable in terms of the energy and momentum that are being injected into the ISM, strongly suggesting that the gas is being blown away from the system isotropically, likely reflecting a cathartic state on its road to becoming an un-obscured quasar. Caught at a time when the Universe was ramping up to its peak of star formation and SMBH accretion, our ALMA observations clearly reveal extreme conditions in the ISM of the most luminous galaxy known, where the feedback from the powerful active galactic nucleus is having a strong impact on the evolution and fate of the entire system.

Kevin Flaherty (Wesleyan University)

A Meredith Hughes (Wesleyan University)
Sean Andrews (CfA)
Eugene Chiang (UC Berkeley)
Jacob Simon (Southwest Research Institute)
Sanaea Rose (Wellesley College)

Weak Turbulence Amid Complex Structure in the HD 163296 Protoplanetary Disk

Turbulence within protoplanetary disks plays a crucial role both in the formation of planetesimals, and in setting the chemical structure of the disk. I will report on a new constraint on turbulence in the disk around HD 163296, a nearby A star, based on ALMA observations of CO and DCO+ emission. These lines probe both the warm surface layers and cold midplane, allowing for a constraint on turbulence throughout the full vertical extent of the outer disk. These data place upper limits on the turbulence (¡0.04cs) that fall approximately an order of magnitude below that predicted by models of full-blown magneto-hydrodynamic turbulence driven by magnetorotational instability. In measuring turbulence, we also find evidence for three distinct rings of DCO+ emission, the inner two of which fall on either side of the CO ice line. The CO ice line is also associated with enhanced dust emission, indicating a complex radial structure within this system. I will discuss the implications of these results in the context of planet formation, and the potential for further ALMA constraints on turbulence.

Seiji Fujimoto (University of Tokyo)

Masami Ouchi (University of Tokyo)
Hiroyuki Hirashita (Academia Sinica Institute of Astronomy and Astrophysics)
Andrea Ferrara (Scuola Normale Superiore)
Takaya Nozawa (National Observatory of Japan)
Hiroshi Nagai (National Observatory of Japan)

ALMA Demographics of [CII]158um and Dust Emission in Star-Forming Galaxies at z 5-9

We present statistics of [CII]158um-line and dust-continuum emission for star-forming galaxies at z∼5-9. The largest sample ever made for z ∼ 5-9 galaxies are composed of 26 and 137 galaxies by the combination of our ALMA Band 6/7 observations to analyze the [CII] and dust-continuum emission, respectively, including sources with strong gravitational magnifications. We obtain the $L_{[CII]}$ - SFR relation that includes the stacking of no detection data, and find that the stack of z∼5-7 Lyman alpha emitters places a stringent upper limit in L([CII]) suggesting a very low metallicity (Z= 0.05 $Z_{\odot}$). We evaluate the infrared-to-UV luminosity ratio, IRX(=L_{IR} / L_{UV}), as a function of UV-continuum slope beta. The IRX-beta plot indicates that the average IRX of z 5-9 galaxies is smaller than the IRX-beta relation predicted by the SMC extinction law. These results suggest that ALMA [CII] and dust-continuum emission in z 5-9 galaxies are systematically weaker than star-forming galaxies at low redshifts. We compare these ALMA emission properties with theoretical models, and discuss the physical origins of the weak ALMA emission.

Yu Gao (Purple Mountain Observatory)

Yinghe ZHAO (Yunnan Observatory)
Nanyao LU (CASSACA National Astronomical Observatories)
C Kevin XU (IPAC Caltech)
Chen CHAO (Shandong Univ Weihai)
et al

ALMA CO(6-5) Imaging of Local Luminous Infrared Galaxies

We present a summary of our ALMA band-9 CO(6-5) imaging observations in 6 nearby luminous infrared (IR) galaxies (LIRGs). CO(6-5) probes the warm and dense molecular gas and shows the tightest linear correlations with the far-IR (i.e., the star formation rate) in galaxies. Our ALMA images with superb angular resolutions as good as ∼0.13" (corresponding to ∼35pc) explore the physical conditions in cold dust and warm/dense molecular gas at a spatial resolution on the characteristic size-scale of GMCs. A variety of CO(6-5) morphology and kinematics in nuclear regions of AGN/starburst from clumpy chaotic ∼kpc disk with starburst ring of radius 50pc, nuclear starburst ring of ∼200pc, to compact AGN/starburst and that with possible warm/dense gas outflows reveals the complex process in the fueling dense molecular gas into central nuclear regions, the heating/cooling of the gas and dust, and the feeding the compact starbursts/AGNs. There are also a similar number of LIRGs with CO(6-5) images in the ALMA archive, but with an overall bias towards ultraluminous advanced mergers. Together with our own sample covering more typical LIRGs, this modest sized sample starts to open up for the rare opportunity to study how the nuclear dense gas configuration evolves over the merger sequence at resolutions of tens of pc.

Sunil Golwala (Caltech)

Dust-Enshrouded Galaxy Evolution at z > 4 with the Chajnantor Sub/millimeter Survey Telescope

The Chajnantor Sub/millimeter Survey Telescope (CSST) will be a 30-m telescope operating at an excellent site in Chile at wavelengths as short as 850 m with 1 degree field of view for imaging and multi-object spectroscopic surveys. In the area of galaxy evolution, CSST will: trace the evolution of dusty, star-forming galaxies from high redshift to the z 1-3 epoch when they dominate the cosmic star formation rate; connect this population to the high-redshift rest-frame UV/optical galaxy population; discover the dust-enshrouded progenitors of the most massive galaxies at z = 4-8; and use these dusty galaxies, the most biased overdensities, to guide ultra-deep followup at $z > 3.5$ and possibly $z > 7$. CSST will also impact our understanding of star formation, of the structure and evolution of galaxy clusters, and of cosmology via the cluster peculiar velocity field. We will describe planned galaxy evolution studies with CSST, the novel telescope design, and the planned survey instrumentation.

Bitten Gullberg (Durham University)

Ian Smail (Durham University)
Mark Swinbank (Durham University)

High-resolution ALMA Observations of ALMA-identified High-z SMGs

I will present high resolution (0.03-0.1") continuum and [CII] emission line maps of sub-mm galaxies (SMGs) selected from the ALMA-LESS and ALMA-UDS surveys. These cycle 2 & 3 observations resolve the gas and dust within the ISM of these galaxies on 0.2-1kpc scales. The data reveal a range of morphologies, but in many cases the gas and dust is much more compact than the stellar light with star-forming "clumps" seen on 200pc scales. I will show how these observations can be used to measure the internal properties of the ISM on 200pc scales, and how they are related to the rapidly reforming disks in these post-merger events.

Antonio Hales (ALMA NRAO)

Antonio Hales (ALMA NRAO)
John Carpenter (ALMA NRAO)

Molecular Gas in Young Debris Disks

We have recently conducted an ALMA 12CO J=2-1 survey towards young, luminous debris disks in the Scorpius-Centaurus OB Association to constrain the lifetime of gas in planet-forming disks. 12CO J=2-1 emission from three debris disks is detected, and marginally resolved at 1-1.5" resolution. By applying the iterative Lucy-Richardson deconvolution technique to the problem of circumstellar disks we are able to reconstruct the CO surface brightness brightness distribution. In the case of HIP 73145 (HD 131835), the CO emission is confined to a ring within 50 and 150 AU. We discuss these results in the frame of the possible origin of the circumstellar gas.

Antonio Hales (JAO and NRAO)

Ed Fomalont (JAO and NRAO)
Meredith Hughes (Wesleyan University)
Uma Gorti (SETI Institute and NASA)
Kevin Flaherty (Wesleyan University)

ALMA Astrometric Precision and the Core Shift in the Giant Radio Galaxy Pictor-A

From test observations during the ALMA long baseline campaign in 2015, we obtained absolute position accuracies of 0.5 mas from ICRS quasars using a multi-source calibration technique. These results and the suggested strategy for future PI ALMA astrometric observations are outlined. One result of these observations is the measurement of the change of position with frequency of the radio core associated with the giant radio galaxy Pictor-A. Its position shift with frequency is caused by the changing optical depth of the dense plasma in the inner part of the jet radio. Using multi-frequency observations from the VLA, VLBI and ALMA we estimate the jet plasma density and its relationship to the massive object and accretion disk within the 16-mag N-type galaxy with a redshift of 0.0342.

Nanase Harada (ASIAA)

Kazushi Sakamoto (ASIAA)
Sergio Martin (JAO)
Yoshimasa Watanabe (University of Tokyo)
Francesco Costagliola (Chalmers Onsala)
Susanne Aalto (Chalmers Onsala)

Chemical Study in Starburst Galaxies

We present preliminary results of ALMA multi-species molecular observations in starburst galaxies M 83 and NGC 3256.

We observed the circumnuclear ring region of a barred spiral galaxy M83. The gas inflow from the bar can cause an evolution of molecular cloud along the orbit of the circumnuclear ring. We study such chemical evolution along the orbit using shock tracers, star-forming core tracers, and PDR tracers.

NGC 3256 is an infrared luminous merger. The chemistry in NGC 3256 is significantly different from another merger Arp 220. NGC 3256 has less complex molecules than Arp 220. We present its spatially-resolved chemistry.

Tetsuo Hasegawa (NAOJ)

Aya Higuchi (RIKEN)
Kazuya Saigo (NAOJ)
Patricio Sanhueza (NAOJ)
James Chibueze (Univ of Nigeria)

ALMA Reveals a Hub of Filamentary Molecular Clouds In Sgr B2(N)

We present $C^{18}O$ (1–0) images of Sgr B2(N), a region of massive star formation, by analyzing the archival ALMA data analyzed by Higuchi et al. (2015, ApJ 815, 106). The synthesized beam is 1.6" × 1.2" (0.06 pc × 0.05 pc at the distance of 7.8 kpc). The massive dense core of Sgr B2(N) is resolved into a hub of filamentary molecular clouds. The typical width and column density of the filaments are 0.08 pc and 5×10^{22} cm^{-2}, respectively (beamwidth uncorrected), which correspond to the typical line mass of 60 $M_{\odot}$/pc for the filaments (assuming optically thin $C^{18}O$ (1–0) emission at $T_{ex} = 50$ K, $[C^{18}O]/[H_2] = 1 \times 10^{-7}$). The hub is centered at the position of the compact continuum source K2, the center of the system of a rotating core and a massive bipolar outflow reported by Higuchi et al. (2015). The filaments exhibit the general velocity gradient from east to west consistent with the steep velocity structure noted by Hasegawa et al. (1994, ApJL 429, L77) in the context of a cloud collision, while some filaments are aligned with the bipolar outflow suggesting a possible feedback origin for them. We discuss formation mechanisms of the massive dense core with the observed filamentary structure.

Bunyo Hatsukade (NAOJ)

Number Counts Derived from the SXDF-ALMA 2 Arcmin^2 Deep Survey

We present 1.1 mm number counts revealed with the ALMA in the Subaru/XMM-Newton Deep Survey Field (SXDF). The advent of ALMA enables us to reveal millimeter-wavelength number counts down to the faint end without source confusion. However, previous studies are based on the ensemble of serendipitously-detected sources in fields originally targeting different sources and could be biased due to the clustering of sources around the targets. We derive number counts in the flux range of 0.2-2 mJy by using 23 ($\geq 4\sigma$) sources detected in a continuous 2.0-arcmin^2 area of the SXDF. The number counts are consistent with previous results within errors, suggesting that the counts derived from serendipitously-detected sources are not significantly biased, although there could be field-to-field variation due to the small survey area. By using the best-fit function of the number counts, we find that 40% of the extragalactic background light at 1.1 mm is resolved at 1.1 mm flux density above 0.2 mJy.

Natsuki H Hayatsu (University of Tokyo)

Y Matsuda (National Astronomical Observatory of Japan)
H Umehata (National Astronomical Observatory of Japan)
I Smail (Durham University)
R Ivison (University of Edinburgh)
M A Swinbank (Durham University)

A Search for $z = 6$ [CII] Emitters in ALMA Cycle 2 Deep Survey Data

We present a result of blind search for [CII] 158 μm emitters at $z = 6$ using deep, contiguous 1.1mm survey data taken in ALMA Cycle2 (ALMA Deep Field 22; ADF22). This search is aimed to constrain $z \geq 6$ [CII] luminosity function for the first time and to study the evolution of high-z star formation history. The observed area of our data is 2×3, angular resolution is 0.6 and rms is 0.5 mJy beam^{-1} at 100 km s^{-1} velocity resolution. We found 2 [CII] emitter candidates above 6 σ ($\sim 3 \times 10^8$ L$_\odot$) in the survey volume of 2200 cMpc^3. The star formation rates (SFRs) of the [CII] emitter candidates are estimated to be $\sim 8 - 30$ M$_\odot$ yr^{-1} by using the empirical [CII]-SFR relation. Assuming the two sources are [CII] emitters, we derive a lower limit of [CII]-based star formation rate density (SFRD) at $z = 6.2$, which is consistent with the UV-based SFRD. This results implies the true SFRD in early universe, which might be estimated from total [CII]-based SFRD, exceeds the UV-based SFRD. Our blind line emitter survey demonstrates that future sub-millimeter deep surveys enable us to understand full picture of cosmic star formation history in the early Universe.

Nathanial Hendler (Lunar and Planetary Laboratory University of Arizona)

I Pascucci (Lunar and Planetary Laboratory The University of Arizona)
ALMA Chameleon I disk team

A Steeper than Linear Disk Mass-Stellar Mass Scaling Relation

The frequency, size and location of planets is strongly affected by the circumstellar disk mass. We present dust disk masses around objects from 2 to 0.03 solar masses from our ALMA 887 m survey of the nearby 2 Myr-old Chamaeleon I star-forming region. We detect thermal dust emission from 66 out of 93 disks. By converting the 887 m flux densities to dust disk masses, we find that the dust disk mass stellar mass relation is steeper than linear with a power-law index of 1.4-1.9. We demonstrate that the regions of Taurus, Lupus and Cha I have the same dust-disk stellar mass relation while the Upper Sco association has a steeper relation. Theoretical models of grain growth, drift, and fragmentation reproduce these trends and suggest that disks around lower-mass stars have smaller sizes than those around higher-mass stars. Finally, we discuss the role of dust disk temperatures/disk sizes on the disk mass estimates.

Naomi Hirano (ASIAA)

His-Wei Yen (ASIAA ESO)
Hauyu Baobab Liu (ESO)
Pin-Gao Gu (ASIAA)
Chin-Fei Lee (ASIAA)
Evaria Puspitaningrum (Institut Teknologi Bandung)

Footprints of Baby Planets; Gas Gaps in the HL Tau Disk

In order to search for the evidence of gaps in the gaseous disk around HL Tau, we have analyzed the HCO^+ 1–0 data obtained from the ALMA long baseline campaign. The HCO^+ image cube at an angular resolution of ∼0.07" (∼10 AU) was azimutally averaged and enhanced its signal-to-noise ratio. The radial intensity profile of HCO^+ shows two gaps at radii of ∼28 and ∼69 AU and a central hole. The inner HCO^+ gap is coincident with the continuum gap at a radius of 32 AU. The outer HCO^+ gap is located at the continuum bright ring at a radius of 69 AU, and overlaps with the two adjacent continuum gaps at radii of 64 and 74 AU. On the contrary, the central hole seen in the intensity profile is likely due to the high optical depth of the 3 mm continuum emission, and not due to the depletion of HCO^+ gas. The two gaps having a width of ∼14 AU are clearly seen in the HCO^+ column density profile. The depths of the inner and outer gaps are ∼2.4 and ∼5.0, respectively. Our results have revealed the presence of gaps in a gaseous disk for the first time. The observed HCO^+ gaps are consistent with those opened due to tidal interaction with (sub-)Jovian mass protoplanets.

Tomoya Hirota (NAOJ)

Kazuhito Motogi (NAOJ)
Naoko Matsumoto (NAOJ)
Mareki Honma (NAOJ)
Masahiro Machida (Kyushu University)
Yuko Matsushita (Kyushu University)

High Resolution Imaging of Disk/Outflow System In Orion Source I

We present results from high-resolution (0.1”=42AU) ALMA cycle 2 observations of H2O and SiO lines at bands 8 toward a radio Source I in Orion KL. We detect 10 H2O, SiO, and their isotopologues including those at vibrationally excited state. The lower excitation H2O and SiO lines trace the northeast-southwest bipolar outflow with the scale of 200 AU while the higher excitation lines are mostly emitted from a compact structure smaller than <100 AU. They show clear rotation signatures around the outflow axis. We will discuss physical and dynamical properties of the disk/outflow system around a massive protostar candidate Source I.

Jane Huang (Harvard-Smithsonian Center for Astrophysics)

Karin Oberg (Harvard-Smithsonian Center for Astrophysics)
Yuri Aikawa (University of Tsukuba)
Sean Andrews (Harvard-Smithsonian Center for Astrophysics)
Kenji Furuya (University of Tsukuba)
Viviana Guzman (Harvard-Smithsonian Center for Astrophysics)

An ALMA Survey of Deuterium Chemistry in Protoplanetary Disks

The deuterium enrichment of molecules is sensitive to their formation environment. Constraining patterns of deuterium chemistry in protoplanetary disks is therefore useful for probing how material is inherited or reprocessed throughout the stages of star and planet formation. We present ALMA observations of DCO^+, $H^{13}CO^+$, DCN, and $H^{13}CN$ in the full disks around T Tauri stars AS 209 and IM Lup, the transition disks around T Tauri stars V4046 Sgr and LkCa 15, and the full disks around Herbig Ae stars MWC 480 and HD 163296. We find efficient deuterium fractionation for the sample, with DCO^+ and $H^{13}CO$+ detected in all disks and DCN and $H^{13}CN$ in all but the IM Lup disk. Not all disks exhibit the expected spatial differentiation between DCN and DCO^+, implying that multiple formation pathways may be needed to explain the diverse emission morphologies. Furthermore, contrary to suggestions based on previous disk observations, our results indicate that DCO^+ is not a simple tracer of the CO snowline.

Nuria Huelamo (CAB INTA-CSIC)

de Gregorio-Monsalvo I (ALMA Chile)
Palau A (UNAM Mexico)
Barrado D (CAB Spain)
Bayo A (U de Valparaiso Chile)
Ru z M T (U de Chile Chile)

Searching for Proto-Brown Dwarfs with ALMA in the Dark Cloud Barnard 30

Brown dwarfs are primarily formed like low-mass stars, although the details of the formation process are still under discussion. To shed light on this formation process, we have studied the population of proto brown dwarfs in the young cloud Barnard 30 (B30) in the Lambda Orionis Star forming region. We have obtained ALMA 850 microns continuum observations of 30 sub-mm sources previously identified with APEX/LABOCA, and reported the detection of five spatially unresolved sources. Three of these sources do not show IR counterparts up to 70 microns and can be classified as starless cores. Their estimated masses using the ALMA data are between 0.9 and 9 Jupiter masses. Based on the core masses derived with APEX/LABOCA, we estimate final masses for these three central objects in the substellar domain, so they can be classified as pre-BD core candidates. We have discussed the properties of these pre-BD core candidates in the framework of the turbulent fragmentation scenario.

Liz Humphreys (ESO)

Maud Galametz (ESO)

Extragalactic Water Megamasers using ALMA Band 5

Water megamaser galaxies have become the object of extensive study at 22 GHz, since the discovery that the emission traces a sub-parsec scale portion of the circumnuclear disk in NGC 4258, within 1 pc of the supermassive black hole (SMBH). Very Long Baseline Interferometry (VLBI) observations of the masers have provided detailed information on the kinematics and structure of Active Galactic Nuclei (AGN). Geometric modelling of VLBI disk maser data, provided acceleration or proper motion measurements are also possible, can be used to perform maser cosmology, and has yielded high-accuracy Hubble constant estimates. Additionally, water megamasers can originate from the interaction of AGN jets with the interstellar medium, probing shocked gas within 1 10 pc of the central regions.

Using APEX SEPIA Band 5 (an ALMA Band 5 receiver on the APEX telescope), we have made a first detection of 183 GHz water megamaser emission towards Seyfert 2 galaxy NGC 4945 and have made an additional observation of this megamaser towards ULIRG Arp 220. The detection towards NGC 4945, of peak flux density 3 Jy, is the strongest extragalactic mm/submm water maser emission detected to date. We believe this to be associated with the AGN central engine and to arise from high density gas (10^8 to 10^{10} cm^{-3}). On the other hand the emission from Arp 220 has a peak flux density of about 150 mJy and appears to be associated with the starburst and traces lower density conditions ($< 10^6 cm^{-3}$). In this talk, we will present the observations and discuss the prospects for high spatial resolution Band 5 followup using ALMA.

Liz Humphreys (ESO)

Rie Miura (NAOJ)
Crystal Brogan (NRAO)
John Hibbard (NRAO)
Todd Hunter (NRAO)
Remy Indebetouw (NRAO)

The ALMA Science Pipeline: Current Status

The ALMA Science Pipeline is being developed for the automated calibration and imaging of ALMA interferometric and single-dish data. The calibration Pipeline for interferometric data was accepted for use by ALMA Science Operations in 2014, and for single-dish data end-to-end processing in 2015. However, work is ongoing to expand the use cases for which the Pipeline can be used e.g. for higher frequency and lower signal-to-noise datasets, and for new observing modes. A current focus includes the commissioning of science target imaging for interferometric data. For the Single Dish Pipeline, the line finding algorithm used in baseline subtraction and baseline flagging heuristics have been greately improved since the prototype used for data from the previous cycle. These algorithms, unique to the Pipeline, produce better results than standard manual processing in many cases. In this poster, we report on the current status of the Pipeline capabilities, present initial results from the Imaging Pipeline, and the smart line finding and flagging algorithm used in the Single Dish Pipeline. The Pipeline is released as part of CASA (the Common Astronomy Software Applications package).

Satoru Iguchi (NAOJ)

Masao Saito (NAOJ)

Large Aperture Millimeter/Submillimeter Telescope: Aperture Synthesis Telescope vs Large Single Dish Telescope

The Aperture Synthesis Telescope can achieve a huge aperture with more than 100-m diameter with the advent of JVLA, ALMA and SKA, but it still has some scientific weak points due to technological limitations: for instance, small field of view. On the other hand, while the Single-dish Telescope can achieve a wide field of view with a multi-pixel radio camera and a multi-beam heterodyne receiver, it also has a disadvantage of requiring a huge aperture (diameter) to achieve high sensitivities, due to several technological limitations. We aim to identify what technological development items need to be addressed from scientific requirements based on several science use cases (e.g. wider field of view, higher sensitivity, higher angular resolution and wider bandwidth), by investigating advantages and disadvantages of both the Aperture Synthesis Telescope and the Large Single-dish Telescope, including comparative analysis of their cost effectiveness. These study results will be presented as a proposal of the design of antenna structure for a future telescope project at millimeter and submillimeter wavelengths.

Daisuke Iono (NAOJ)

Min S Yun (UMass)
and the high-resolution SMG team

Central Regions of the Brightest Unlensed Submillimeter Galaxies

The central structure in three of the brightest unlensed $z = 3 - 4$ submillimeter galaxies are investigated through 0".015 – 0".05 (120 - 400 pc) 860μmcontinuum images obtained using the longest baselines of Cycle 3 ALMA. The distribution in the central kpc in two sources are extremely complex, and they are composed of multiple clumps with size scale of 200 - 300 pc. One galaxy consists of two sources that are separated by 1.5 kpc, indicating a mid-stage merger. The peak Star Formation Rate (SFR) densities in the central clumps are very high, suggesting regions with extreme star formation near the Eddington Limit. We identify at least five additional extremely compact and massive clumps in the extended 3-4 kpc region in one of the sources. Overall, the data presented here suggest that the sizes and surface densities of the central kpc of the brightest SMGs are similar to the central regions of the brightest ULIRGs in the local universe. Between 10 to 30% of the 860μmcontinuum is concentrated in clumpy structures in the central kpc while the remaining flux is distributed over the $\gtrsim$ 1 kpc regions, some of which could also be clumpy. All three sources can be explained by mergers of gas-rich galaxies, with the surrounding medium forming an extended and clumpy star-bursting disk.

Natsuko Izumi (National Astronomical Observatory of Japan)

Masao Saito (National Astronomical Observatory of Japan)
Chikako Yasui (National Astronomical Observatory of Japan)
Leonardo Bronfman (University of Chile)
Kengo Tachihara (Nagoya University)

Studying Properties of Dense Core in the Outer Galaxy with ALMA

The outer part of the Galactic disk has different environment from the inner disk including smaller cosmic-ray flux density, less intense UV field, and smaller external pressure. It is also known that the gas density and metallicity decrease with increasing Galactocentric radius (Rg), and these values go down to be about 20 % of the solar values at Rg 16 kpc. Because such environments may have similar characteristics with dwarf galaxies and the early phase of the formation of our Galaxy, we might be able to directly observe the galaxy formation processes in unprecedented detail at much closer distance (D 10 kpc) than distance galaxies (D $>$ 50 kpc). Our previous 12CO(1-0) observations of molecular clouds in the outer Galaxy suggest that the properties of molecular clumps (pc scale) including Xco conversion factor and velocity width are different from those in the solar neighborhood. On the other hands, our previous studies for star-forming regions in the outer Galaxy suggest that the properties of star-forming regions including the initial mass function and star-formation efficiency per molecular clouds (for converting H2 gas to stars) are the same as those in the solar neighborhood. Thus, as a next step, we need to study properties of dense core in the outer Galaxy and confirm whether the properties, in particularly core mass function, are universal or instead sensitive to environments with ALMA. Using ALMA's high-resolution observation, we will be able to investigate properties of dense core (0.1 pc scale) in the primordial environment for the first time. This study may lead to reveal star formation processes in the early phase of the galaxy.

Hiroyuki Kaneko (Nobeyama Radio Observatory)

Nario KUNO (Takayuki R SAITOH)

Molecular Collision Front at an Overlapping Region of Interacting Galaxies in Early Stage

We present a high resolution ^{12}CO($J = 1$–0) imaging observation of interacting galaxies in the early stage VV 219 (NGC 4567/4568) obtained with ALMA Cycle 1. The data (spacial resolution of $2'' \times 2''$ and velocity resolution of 5 km s^{-1}) reveals a large filamentary molecular structure at an overlapping region. The structure has large velocity width of 50 km s^{-1} which smoothly connects to molecular gas embedded with both progenitors and is located at an edge of the largest star-forming region in the overlapping region. Integrating over the velocity of large velocity width, the size of the filamentary structure is over 2.5 kpc $\times$ 390 pc and molecular gas mass is at least $2.3 \times 10^7\ M_\odot$ assuming the standard CO–H_2 conversion factor. The distribution of the filamentary structure corresponds in position exactly to a dust-lane. These facts suggest that the filamentary molecular structure is made by the collision of the molecular gas discs of NGC 4567 and NGC 4568 at the overlapping region and collision-induced star formation is on-going with molecular gas embedded with the structure as predicted by numerical simulations (Saitoh et al. 2009).

Amanda Kepley (NRAO)

Adam Leroy (Ohio State University)
Kelsey Johnson (University of Virginia)
Karin Sandstrom (University of California San Diego)
C -H Rosie Chen (Max-Planck-Institut für Radioastronomie)

Star Formation in Extreme Environments: The Case of the Prototypical Blue Compact Dwarf Galaxy II Zw 40

With their high star formation rate surface densities and low metallicities, blue compact dwarf galaxies represent one of the most extreme environments for star formation in the local universe: one more akin to that found in high redshift galaxies than in local spirals. Until the advent of ALMA, however, the molecular gas fueling the prodigious star formation in blue compact dwarfs was difficult to observe because these galaxies generally have weak CO emission. In this talk, I present the first detailed study of the molecular gas content (as traced by CO) in the prototypical nearby blue compact dwarf galaxy II Zw 40. The extraordinary resolution and sensitivity of our ALMA Cycle 1 observations have separated the molecular gas emission into discrete giant molecular cloud-sized clumps allowing us to measured properties of individual clouds. We find that molecular clouds within this galaxy have linewidths and surface densities similar to molecular clouds in more massive starburst galaxies, suggesting the the large-scale shocks from II Zw 40s on-going merger are driving the molecular gas properties in this galaxy. Using our estimate of the CO to molecular gas conversion factor, we find that the molecular gas star formation efficiency is an order of magnitude greater than that in normal spiral galaxies and is similar to the star formation efficiencies seen in other starburst galaxy. However, we caution that this value may be an artifact of the recent burst of star formation rather than a galaxies like II Zw 40 in much greater detail than previously possible, but also that building up larger samples of such galaxies in different evolutionary states is crucial to understand these systems as a whole.

Mikyoung Kim (KASI)

Tomoya Hirota (NAOJ)
Kee-Tae Kim (KASI)
KaVA SFR sub-WG members

Understanding High-Mass Star Formation Through KaVA Observations of Water and Methanol Masers

Maser emission from various molecular species are associated with different physical condition and a wide range of evolutionary phase of young stellar objects. Multi-epoch and multi-species maser observations using VLBI enable us to study 3-D structure and dynamics around young stellar objects during overall star forming process. Since 2016, we have started an observational study of 22 GHz water and 44 GHz class I methanol masers in high-star forming regions as a KaVA large program. The science goal is to understand dynamical evolution of high-mass young stella objects and their circumstellar structures by measuring spatial distributions and 3-dimensional velocity fields of multiple maser species. In the first year, we have started snap-shot imaging survey for approximately 100 maser sources, then multi-epoch monitoring observations will be conducted based on the these results. In this poster, we will present brief summary of large program and the initial results of the observations.

Shuo Kong (University of Florida)

Jonathan C Tan (University of Florida)
Paola Caselli (MPE)
Francesco Fontani (INAF)

The Initial Conditions of Massive Star Formation

Massive stars play a crucial role in the evolution of galaxies, yet many open questions remain concerning their formation mechanism. Investigation of the initial conditions of massive star formation can provide crucial insight. Before ALMA we have been severely limited by relatively poor resolution and sensitivity in such studies. Now ALMA is providing advanced capabilities for probing deep into distant Infrared Dark Clouds to look for massive pre-stellar/early-stage cores, the potential initial conditions for massive star formation. Here we report results of several ALMA projects to search for and study massive cores using deuterated species, especially N2D+, in order to test massive star formation theories. Several massive, highly deuterated cores have been detected. Together with astrochemical models of the deuteration process, these results also provide constraints of the evolutionary history of the cores, including the rate of collapse. These studies are being generalized to studies of cores of all masses in an attempt to understand the origin of the stellar initial mass function.

Maciej Koprowski (University of Hertfordshire)

Kristen Coppin (University of Hertfordshire)
James Geach (University of Hertfordshire)

Resolved IRX In a Normal Star-Forming Galaxy at $z = 3$

It is now well established that the global star formation rate density steadily declines beyond $z \sim 3$, however tracing the exact shape of the decline at high-redshift has primarily relied on rest-frame UV selected samples of 'drop-outs' with indirect dust corrections to the UV luminosities being made based on the UV continuum slope (β). And a natural question is whether this IRX-β relation, derived from local star-forming galaxies, can be aplied at high-z. In this vein, we have observed a sample of $z = 3$ LBGs with ALMA at 870μm to compare with the local Meurer et al. (1999) (IRX-Beta) relation as well as other literature values at even higher redshifts and we will discuss the implications for the high-z estimates of the global star formation rate density. Excitingly, we have also resolved the dust continuum in one of our $z = 3$ Lyman-break galaxies – and when combined with its HST $I-$band imaging, we are effectively able to resolve the Infrared Excess (IRX) on sub-galactic scales in a normal star-forming galaxy at $z = 3$ for the first time, revealing the relative spatial extent of the stellar emission and dust absorption on the same scales.

Devaky Kunneriath (NRAO)

Lydia Moser (I Physikalisches Institut Universitaet zu Koeln)
Alvaro Sanchez-Monge (I Physikalisches Institut Universitaet zu Koeln)
Andreas Eckart (I Physikalisches Institut Universitaet zu Koeln)
Miguel Requena-Torres (Space Telescope Institute)
Macarena Garcia-Marin (European Space Agency)

Detection of Molecular Gas in the Galactic Centre Minispiral Region

We present high resolution (0.75") detections of molecular line emission (CS, H13CO, HC3N, SiO, SO, C2H, CH3OH, 13CS, and N2H+) in bands 3, 6 and 7 with ALMA in the central parsec region of the Milky Way Galactic centre at projected distances of < 1" (=0.04pc) from Sgr A*. These clumps of gas are partially spatially overlapping with the Minispiral, the streamers of ionised gas and dust which are thought to connect the Circumnuclear disk (CND), a clumpy disk containing molecular gas and dust, to the central supermassive black hole, Sgr A*. They show three times higher CS/X luminosity ratios (where X is any other molecule detected in the same dataset) than the CND, suggesting a combination of higher excitation - by a temperature gradient and/or IR-pumping - and abundance enhancement due to UV- and/or X-ray emission. Hence, we conclude that this central association is closer to the centre than the CND. In addition, we identified several regions within and outside the CND that call for further studies in the context of infrared dark cloud, hot/cold core, extreme PDR/XDR chemistry and consequent star formation in the central few parsecs.

Seppo Laine (Caltech)

Bruce McCollum (Catholic University of America)
Ryan Lau (JPL Caltech)
Lee Rottler (Catholic University of America)
Fred Bruhweiler (Catholic University of America)

Modeling the Infrared to Sub-mm SED of V1309 Scorpii

The 2008 nova V1309 Scorpii was recently shown to be the first observed merger between two non-degenerate stars. Stellar mergers are thought to be a significant factor in the evolution of stellar clusters and galactic centers, as well as possibly the origin of several types of unusual stars, such as Be stars, sdB stars, and blue stragglers. Despite their importance to several areas of astronomy, mergers are poorly understood because of the lack of models and data to constrain these models. One critical merger model ingredient is the amount of mass expelled from the merger during the outburst (V1309 Sco is also classed as a luminous red nova). Infrared observations of V1309 Sco have shown that there is a substantial amount of dust in the ejecta. We have fitted spectral energy distribution (SED) models, including important upper limits from ALMA observations at 1 to 3 mm, to constrain the mass of the dust around V1309 Sco. Based on our best SED fit, we speculate on the nature of the dust around V1309 Sco.

Rebecca Levy (University of Maryland)

Alberto D Bolatto (University of Maryland)
Dyas Utomo (University of California Berkeley)
Leo Blitz (University of California Berkeley)
Eve C Ostriker (Princeton University)
Tony Wong (University of Illinois)

The EDGE CO Survey of Nearby Galaxies

The CARMA component of the EDGE Survey spatially resolved ^{12}CO(1-0) and ^{13}CO(1-0) in 126 nearby galaxies. The EDGE galaxies were selected from the Calar Alto Legacy Integral Field Area (CALIFA) sample, an optical IFU survey with full spectral information on the stellar and ionized gas components of over 600 nearby galaxies. Combined, these surveys provide a uniquely powerful way to study these galaxies in the context of the gas kinematics and star formation properties. We present the EDGE survey and preliminary results of two ongoing studies. First, CO and ionized gas rotation curves were derived for the 126 EDGE-CALIFA galaxies, and we show preliminary results comparing the molecular and ionized gas kinematics. Secondly, molecular gas depletion times ($\tau_{\rm dep}$) are calculated as a function of radius for the sample. While the majority of galaxies have similar $\tau_{\rm dep}$ (i.e. a linear relation between star formation rate and molecular gas surface density), about 25% of the galaxy centers have shorter $\tau_{\rm dep}$ than in the disks. We investigate several possible causes, such as the presence of bars and the ratio of stellar to molecular gas gravity, in setting the difference of $\tau_{\rm dep}$ between the centers and the disks. With ALMA, we have the unprecedented ability to do large, spatially resolved CO surveys to better understand star formation in the nearby universe.

Sean Linden (University of Virginia)

Eric Murphy (National Radio Astronomical Observatory Charlottesville)
Dillon Dong (California Institute of Technology)
Emmanuel Momjian (National Radio Astronomical Observatory Socorro)
Robert Kennicutt (University of Cambridge)

The Star Formation in Radio Survey: Multi-Frequency Jansky Very Large Array Observations of Nearby Galaxy Nuclei and Extranuclear Star-Forming Regions

We present a set of Jansky Very Large Array (VLA) 33GHz (Ka-Band), 15GHz (Ku-Band) and 3 GHz (S-Band) images of 112 extragalactic nuclei and star-forming regions in 50 nearby ($d \leq 30$Mpc) galaxies taken as part of the Star Formation in Radio Survey (SFRS). The SFRS contains galaxies for which we have mid- and far-infrared spectra taken as part of the Spitzer/SINGS and Herschel/KINGFISH legacy programs, respectively. Our initial investigation includes an estimate of the fraction of diffuse emission that is missed in the Ka-band interferometric images based on comparisons with single-dish GBT measurements at 33GHz. Additionally, 33GHz source morphologies are compared with H-alpha imaging from SINGS, showing that in general the two trace each other very closely. However, in a few cases (e.g., NGC3627, NGC6946) we find evidence for highly-embedded HII regions that are bright in radio continuum at 33GHz, but nearly invisible in H-alpha emission. Finally, we look at side-by-side comparisons of the 33GHz morphologies with the lower frequency Ku- and S-Band data. Many of the S-band images exhibit significantly more diffuse emission surrounding the extranuclear regions in the sample. We interpret this as evidence of recent ($\sim$ 10 Myr) supernova activity followed by subsequent cosmic-ray diffusion surrounding these regions.

Mengyao Liu (University of Florida)

Jonathan C Tan (University of Florida)
Shuo Kong (University of Florida)
Yichen Zhang (Universidad de Chile)

Protostellar Outflows from Infrared Dark Clouds

We present ALMA Cycle 2 observations of SiO(5-4) outflows towards 32 Infrared Dark Cloud (IRDC) clumps, which are spatially resolved down to 0.05pc. Out of the 32 clumps observed, we have detected SiO emission in 14 clumps, and in 6 of them the SiO emission is stronger than 10 sigma noise level with continuum peaks nearby and is considered to trace outflows. We locate the dense gas cores associated with the outflows in position-velocity space utilizing spectral line emission from DCN, DCO+ and C18O. The different morphology and kinematics of the outflows indicate different core structures, accretion history and ambient cloud environment. The mass and energetics of the outflows indicate that the 6 sources are in an early stage as candidates of protostars embedded in massive dense clumps. The comparison of the physical properties of protostellar outflows with theoretical models will shed light on high mass star formation process.

Ryan Loomis (Harvard University)

Karin Oberg (Harvard University)
Sean Andrews (Harvard Smithsonian CfA)
Catherine Walsh (Leiden University)
Jane Huang (Harvard University)
Ian Czekala (Harvard University)

Matched Filter Analysis as a New Method of Detecting Weak Lines

With the improving sensitivity of interferometers, spatially resolved observations of spectral line emission are of increasing importance. Within these datasets, the most interesting features often have the lowest signal to noise. For well-characterized sources, a-priori knowledge of the source structure can be leveraged through the use of a matched filter to increase sensitivity. Applying a matched filter to the data in the native uv plane yields the optimal detection efficiency, while simultaneously eliminating the ambiguities associated with imaging and deconvolution. We demonstrate how an approximate matched filter can be constructed from a previously observed line or model of the source and show how this filter can be efficiently convolved with the measured visibilities to robustly infer a detection probability. When applied to ALMA observations of CH_3OH in the protoplanetary disk TW Hya from Walsh et al. (2016), our matched filter technique yields a $\sim$60% SNR boost over the traditional spectral extraction method. These promising results suggest that as interferometric datasets continue to increase in sensitivity and bandwidth, matched filtering may prove to be a useful tool for fast and robust weak spectral line detection.

A-Ran Lyo (Korea Astronomy and Space Science Institute)

Jongsoo Kim (Korea Astronomy and Space Science Insitute)
Jae-Joon Lee (Korea Astronomy and Space Science Insitute)
Gregory Mace (University of Texas at Austin)
Jihyun Kang (Korea Astronomy and Space Science Insitute)
Kyoung-Hee Kim (Korea Astronomy and Space Science Insitute)

Inner Warm Disk of ClassI ESO H279a Revealed by NaI and CO Overtone Emission Lines

We present analysis of near-infrared, high-resolution spectroscopy towards the Class I YSO (Young Stellar Object) ESO Hα 279a ($1.5 M_{\odot}$) in the Serpens star forming region, at the distance of 429 pc. Employing the Immersion GRating INfrared Spectrometer (IGRINS, $R \approx$45,000), we detect emission lines originating from the accretion channel flow, jet, and inner disk. Specifically, we identify hydrogen Brackett series recombination, [Fe II], [Fe III], [Fe IV], Ca I, Na I, H_2, H_2O and CO overtone emission lines. By modeling five bands of CO overtone emission lines, and the symmetric double-peaked line profile for Na I emission lines, we find that ESO Hα 279a has an actively accreting Keplerian disk. From our Keplerian disk model, we find that Na I emission lines originate between 0.04 AU and 0.78 AU, while CO overtone emission lines are from the outer range between 0.22 AU and 3.00 AU. It reveals that the neutral atomic Na gas is a good tracer of the innermost region of the actively accreting disk.

Nuria Marcelino (ICMM-CSIC)

Jose Cernicharo (ICMM-CSIC)
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Aina Palau (UNAM)

DCN and DNC in Orion KL as seen by ALMA

Large deuterium fractionation has been observed in different environments in the ISM, but its chemical pathways are not yet fully understood. In particular toward warm molecular clouds, where deuteration can be the result of grain mantle desorption or also be produced in the warm gas-phase. High DCN abundances in Orion KL have been explained using both warm gas-phase chemical models (Schilke et al. 1992) and desorption from grain surfaces (Mangum et al. 1991). More recently, the detection of DCN in the Orion Bar (Parise et al. 2009), has also suggested a gas-phase deuteration pathway under moderate warm conditions (50-100 K). Indeed HCN can be efficiently fractionated in warm regions through the CH_2D^+ ion, which will become a more important route to deuteration than H_2D^+ as temperature increases (Roueff et al. 2007). The detection of CH_2D^+ in Orion-KL (Roueff et al. 2013), the only source where this ion has been observed so far, also supports this possible pathway. Although DNC is also produced via CH_2D^+ + N, with equal rate coefficients than DCN, its abundance is much lower due to destruction of both HNC and DNC at high temperatures.

We present ALMA observations at $1-2$" of angular resolution showing the different spatial distribution of both isomers, and suggesting different deuteration processes at work. While DCN is mainly arising from a N-S filament close to the Hot Core and other positions related to infrared sources, DNC shows emission on a position to the west not associated with any known IR source and where no continuum or strong HNC emission is detected with ALMA. We will discuss different possibilities to produce this puzzling behaviour between the two isomers.

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Gautier Mathys (JAO)

Pierre Cox (JAO)
John M Carpenter (JAO)

Half a Decade of Proposal Review at ALMA

Proposals for observations with ALMA are selected through a single peer review process. From the first review cycle (Cycle 0) to the most recent one (Cycle 4), the number of submitted proposals has increased by more than 70%, and it is now reaching close to 1600. In response to this increasing demand, from cycle to cycle, ALMA has made adjustments to its review process so as to ensure that the workload of the assessors was kept to a manageable level and with a view to optimizing the quality of the evaluations and the fairness of the proposal selection. Developments were also introduced to accommodate the handling of new types of proposals (such as Large Proposals and mm-VLBI Proposals) and new observing modes (such as non-standard and ACA-standalone observing modes). We present an overview of the evolution that has taken place until now, summarize the current review procedure, and sketch prospects for the future.

Yuichi Matsuda (NAOJ)

ALMA 860um Continuum Observations of Lyman-alpha Blobs at z=3.1

Lyman-alpha blobs (LABs) are giant Lyman-alpha emitting nebula and are a key population to understand large-scale gas circulation processes between young galaxies and their surroundings during the era of galaxy formation. We present 0.3" resolution sub-millimeter observations of four giant (100kpc-scale) LABs at z=3.1 with ALMA. On the 860um continuum maps with a sensitivity of rms=0.04mJy/beam, we detected 6 continuum sources above a 5-sigma level in the LABs. The measured source sizes range 0.1-0.4" (1-3kpc). We found that the star-formation rate (SFR) surface densities of the ALMA sources range 4-30Msun/yr/kpc^2, which exceed the threshold of gas outflows from high-redshift star-forming clumps. This result suggests that star-burst driven outflows may increase the covering fraction of gas in the halos and produce the extended gaseous structure of LABs.

Luke Maud (Allegro Dutch ALMA Arc Node Leiden Observatory)

Melvin Hoare
Roberto Galvan-Madrid
Katharine Johnston
Qizhou Zhang
Willem-Jan de Wit

W33A - The sub-arcsecond view with ALMA

We targeted the massive star forming region W33A using the Atacama Large Millimetre Array (ALMA) in band 6 (230 GHz) and band 7 (345 GHz) to search for a potential large, ∼1000 au radii disk around the central O/B-type massive young stellar object (MYSO) W33A MM1-main as was hinted at in previous studies with the Sub Millimetre Array (SMA). Our data achieving a resolution of ∼0.2 (or ∼500 au) reveals a marginally resolved central core with a large scale, extended, complex envelope and more distant filamentary structures. There is strong and rich molecular emission from the entire region. The CH_3CH lines indicate a much more complex kinematic environment beyond a simple Keplerian rotating disk. Such kinematics are likely the culmination of rotation, infall and outflow onto the MYSO, although we cannot rule out the possibility a binary or multiple system at smaller scales (<500 au). W33A MM1-main, and 2 other YSOs in the region drive strong outflow as detected in SiO (8-7).

Brett McGuire (NRAO)

Looking for Life in All the Wrong Places

The search for glycine, the simplest amino acid, has been an ongoing effort in the astrochemistry community for the last several decades. Given the challenges of a complex spectrum of low-intensity lines needing long integration times, identifying target sources rich in potential precursor molecules is appealing. One such potential precursor molecule, the comparatively simple hydroxylamine (NH2OH), has long eluded detection. Our most recent search, in the nearby NGC 6334I region, has shown an incredibly rich chemical inventory, but no clear signal from NH2OH. Despite this, the ALMA spectra show a fascinatingly oxygen-rich chemistry, with the clearest detection of acetic acid to date, and a surprising lack of nitrogen-bearing species. I will present preliminary results, and a look forward to areas of exploration with the data set. Ideas for collaboration are most welcome.

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Brian Kirk (NRAO)
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Devaky Kunneriath (NRAO)

ALMA Data Structures and the Science Archive

The ALMA Science Archive (ASA) is a foundational design element of the ALMA project. The ASA currently holds over 108TB of data from diverse science projects, accounting for more than 11,500 hours of observing time. To assist users of the ASA in successfully utilizing this resource, we explain the ALMA Calibration and Imaging Pipeline ObsUnitSet (OUS) hierarchy, ALMA Science Data Model, and Measurement Set format. We also illustrate the data structures resulting from successful queries of the ASA database. Finally, we provide historical context for the present and future operation of the ASA and summarize the available documentation.

Tomonari Michiyama (NAOJ SOKENDAI)

Daisuke Iono (NAOJ SOKEDAI)
Junko Ueda (CfA)
Min Yun (UMass)
Toshiki Saito (University of Tokyo)
Kouichiro Nakanishi (NAOJ SOKENDAI)

Chemical Composition in a Merging Galaxy NGC 3256 -ALMA Cycle3 Observation

We report new ALMA Cycle 3 results of molecular line survey towards a late stage merging galaxy NGC 3256. NGC 3256 hosts two merging nuclei, and the starburst and AGN activities are strongly affecting the chemical and physical properties of the ISM. We have detected more than 20 molecules (e.g., c-C_3H_2, $H^{13}CN$, $H^{13}CO^+$, SiO, CCH, HCN, HCO^+, HNC, CH_3OH, CS, HC_3N, CH_3CCH, $C^{18}O$, ^{13}CO) at 2 angular resolution, which is high enough to distinguish double nuclei. We detected SiO and CH_3OH between the two nuclei, and this is possibly tracing the region where shocked gas is enhanced by the collision front. In addition, we find that the HCN/HCO^+ ratio, which is often used to trace buried AGNs, is $\sim$1.0 at the northern nucleus and < 1.0 at the southern nucleus. The high ratio in the northern nucleus suggests the presence of an AGN, but this is inconsistent with the previous studies (X-ray, H_2-line, CO kinematics, and SED fitting) which suggest that the northern galaxy is a starburst dominated galaxy. We discuss how the galaxy collision, starburst, and AGN affect the chemistry of NGC 3256.

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Investigating the Relation between CO (32) and Far Infrared Luminosities for Nearby Merging Galaxies Using ASTE

We present the new ASTE CO (3-2) observation toward 19 early stage and 7 late stage nearby merging galaxies. Combining with the previous studies, we investigate the relation between the CO (3-2) luminosity (L'CO(3-2)) and the far Infrared luminosity (LFIR) in a sample of 29 early and 31 late stage merging galaxies, and 28 nearby isolated spiral galaxies. We find that normal isolated spiral galaxies and merging galaxies have different slopes in the logL'CO(3-2)-logLFIR plane (0.79 for spirals and 1.12 for mergers). The large slope (>1) for merging galaxies can be interpreted as an evidence for increasing Star Formation Efficiency (SFE=LFIR=L'CO(3-2)) as a function of LFIR. Comparing our results with sub-kpc scale local star formation and global star-burst activity in the high-z universe, we find deviations from the linear relationship in the logL'CO(3-2) - logLFIR plane for late stage mergers and high-z star forming galaxies. Finally, we find that the average SFE gradually increases from isolated galaxies, merging galaxies, and to high-z SMG/QSOs. By comparing our findings with the results from numerical simulations, we suggest; (1) inefficient star-bursts triggered by disk-wide dense clumps occur in the early stage of interaction and (2) efficient star-bursts triggered by central concentration of gas occur in the final stage. A systematic high spatial resolution survey of diffuse and dense gas tracers is a key to confirm this scenario.

Rie Miura E (NAOJ)

DANIEL ESPADA (NAOJ)
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HAJIME SUGAI (IPMU)
HIROTA AKIHIKO (NAOJ)

The Super-Star-Cluster Forming Cloud in the Nearest Young Starburst Galaxy NGC5253

The starburst is one of the largest star formation events in the Universe. The massive and compact stellar clusters, what is so-called super stellar clusters (SSCs), are often found in there, and seem to play a significant role in cycling gas and dust by outflow or inflow, which is becoming evident thanks to the recent high resolution and sensitivity data with ALMA. In this poster, we present the ALMA Cycle 2 observations toward the nearest young starburst galaxy NGC5253, which hosts two young (1Myr) SSCs in its nuclear starburst region. From the ALMA CO(2-1) data a total of 59 molecular clouds are identified using SCIME and has a typical size of 7 pc and a velocity width of 2 km/s. Among them, we found that there is large velocity width compact clouds in its center, where one of the young SSCs is located, while there is less molecular gas around the other SSC. We discuss several possibilities that cause such large velocity width of the SSC-forming clouds, and also mortality of molecular gas around the SSCs.

Yusuke Miyamoto (Nobeyama Radio Observatory)

Naomasa NAKAI (University of Tsukuba)
Masumichi SETA (Kwansei Gakuin University)
Dragan SALAK (Kwansei Gakuin University)
Makoto NAGAI (University of Tsukuba)
Hiroyuki KANEKO (Nobeyama Radio Observatory)

ALMA View of the Central Region of NGC 613

For understanding activity and evolution of active galactic nuclei (AGN), it is essential to investigate the fueling and feedback processes in AGN. Recent observations have showed that jet/outflow activities from AGNs can heavily influence the fueling process. A nearby Seyfert galaxy NGC 613 is one of the best targets for studying the jet/outflow activities due to the proximity, relatively abundant molecular gas around the center, the activity shown by the radio jet and the nuclear ring with moderate inclination.

We carried out observations of NGC 613 in Band3 and Band7 with ALMA. Using the archival 4.9 GHz data and our 95 GHz data, the spectral indices of -0.7 and -0.2 were derived along the jet and in the star forming ring, which can be produced by synchrotron emission and free-free emission, respectively. In addition, CO(3-2), HCN(1-0), HCN(4-3), HCO^+(1-0), HCO^+(4-3), CS(2-1) and CS(7-6) emission was detected from both the circum-nuclear disk (CND) and the ring. We found that the rotational temperature derived from the HCN, HCO+ and CS lines decreased with distance from the center and the ratios of HCN/HCO^+ and HCN/CS at the CND were consistent with those of other AGNs already reported.

Jacqueline Monkiewicz (Arizona State University)

Kenworthy Matthew
Klaassen Pamela
Mamajek Eric (University of Rochester)

ALMA and JVLA Observations of the J1407b Exoring System

The 16 Myr old pre-main sequence star 1SWASP J1407 was eclipsed by a giant, highly structured ring system that encircles a substellar companion, dubbed J1407b. A 54-day eclipsing event in Apr/May 2007 revealed multiple ring crossing events, indicative of a large ring system composed of dust and possibly sculpted by exomoons. Given the age of the host star, the most favorable interpretation is of a proto-satellite disk system left over from the nebular accretion phase of the substellar companion. However, no additional eclipses have since been observed, meaning the orbit, size, and dust mass of this exoring system remain largely unconstrained.

Only the JVLA and ALMA have adequate sensitivity and resolution to directly map the orbit of the exoring system; together, these two telescopes provide critical constraints on the emission from larger millimeter- to centimeter-sized dust particles. We will therefore combine JVLA Q-band (45 GHz) observations with ALMA band 7 (345 GHz) ALMA observations in order to 1.) confirm the presence of an early exoring system orbiting J1407, 2.) measure emission from the larger millimeter- and centimeter-sized dust particles, and 3.) constrain the total dust mass of the exoring system. If detected, these observations will be the first direct detection of an proto-satellite system, and will provide astrometric data that will determine the epoch of the next eclipse.

Tony Mroczkowski (European Southern Observatory)

Tony Mroczkowski (European Southern Observatory)
Tracy Clarke (Naval Research Laboratory)
Maxim Markevitch (Goddard Space Flight Center)
Brian Mason (NRAO)
Scott Randall (Chandra X-ray Center SAO)

ALMA+ACA Imaging of Shock in the Bullet Cluster through the Sunyaev-Zel'dovich Effect

Galaxy clusters are among the largest gravitationally-bound objects in the Universe and, according to the hierarchical picture of structure formation, are the most recent to form. A crucial aspect of their formation is through mergers, which violently dissipate most of their kinetic energy through shocks. The merger in 1E0657-56 – a.k.a. "the Bullet Cluster" – is one of the cleanest astrophysical labs for shock physics and is among the most energetic events in the visible Universe since the Big Bang itself. The Bullet Cluster provides direct evidence that clusters are dominated by cold dark matter through the large spatial separations between the gas and lensing peaks. We obtained ALMA+ACA Band 3 observations that provide the first sensitive ($\sim$11 μJy/bm), high-resolution ($\sim 5''$) Sunyaev-Zel'dovich effect measurement of the shock front in the Bullet Cluster. We model the ALMA+ACA measurements of the shock testing the models fit to with deep X-ray data from the *Chandra* and NuSTAR X-ray telescopes, and compare these measurements to existing arcminute-resolution measurements to place more direct constraints on the shock energetics and better infer the line of sight distribution of the gas.

Alejandra Munoz Arancibia (Instituto de Fisica y Astronomia Universidad de Valparaiso)

Jorge Gonzalez-Lopez (Instituto de Astrofisica Pontificia Universidad Catolica de Chile)
Eduardo Ibar (Instituto de Fisica y Astronomia Universidad de Valparaiso)
Franz Bauer (Instituto de Astrofisica Pontificia Universidad Catolica de Chile)

Lensing-corrected 1.1mm Number Counts in the ALMA Frontier Fields Survey

We present galaxy number counts around three strong-lensing galaxy clusters as part of the ALMA Frontier Fields Survey. This aims to characterize the population of faint, dusty star-forming galaxies at high redshift, benefiting from the magnification power of the clusters. Our study combines the analysis of deep (rms 55-71 uJy/beam) ALMA 1.1mm continuum data over 4.6 square arcmin, introduced by Gonzalez-Lopez et al. 2016, with gravitational lensing models produced by different groups. We compare our results with current number counts estimates available in the literature.

Lena Murchikova (Caltech)

Nick Scoville

Probing Inner Workings on the Galactic Nuclei with Submm Recombination Lines

We present two examples of using ALMA to study dusty and extreme galactic nuclei Arp220 with its two nuclei and the Milky Way's super massive black hole SgrA*.

Arp220 is the result of two colliding galaxies. It is the best studied ultra-luminous IR galaxy and the host of one of the most extreme star formation in the Universe. We present 80mas 30pc resolution imaging of CO1-0 emission and 3mm dust continuum from Arp 220 obtained with ALMA in cycle 3. The quality and resolution of the images are spectacular. The nuclei are very well separated. The velocity field of the nuclear disks is resolved in fine detail. We will present an analysis of the dynamics of the gas around nucleus, properties of the disks and constraints on the masses of the super massive black holes residing in the nucleus. SgrA* is the closest super massive black hole to Earth. We present the possible detection of broad HI 30alpha recombination emission from the accretion zone of SgrA*.and discuss the properties of ionized hydrogen at 10^4K. Our analysis shows that the radiation detected comes from the distance of 0.001 near SgrA* and the volume of the ionized gas is   0.5 Jupiter mass.

In collaboration with : N. Scoville, F. Walter; C. Vlahakis; J. Koda; P. Vanden Bout; K. Sheth; D. Sanders; L. Armus; P. Cox; L. Tacconi; P. Torrey; C. Hayward; T. Thompson; R. Genzel; B. Robertson; J. Barnes; L. Hernquist; P. van der Werf; R. Decarli

Eric Murphy (NRAO)

Science with a Next Generation VLA

Inspired by dramatic discoveries from the Jansky VLA and ALMA, the U.S. astronomy community has initiated a plan to pursue a future large area radio array that will open new discovery space from proto-planetary disks to distant galaxies. The current vision of ngVLA is an interferometric array with more than 10 times the effective collecting area and 10 times higher spatial resolution than the current VLA and the Atacama Large Millimeter Array (ALMA) that will operate at frequencies spanning 1.2-116GHz. As such, the ngVLA will open a new window on the universe through ultra-sensitive imaging of thermal line and continuum emission down to milliarcecond resolution, as well as deliver unprecedented broad band continuum polarimetric imaging of non-thermal processes. The ngVLA will be the only facility in the world that can tackle a broad range of outstanding scientific questions in modern astronomy by simultaneously delivering the capability to: directly image planet formation in the terrestrial-zone; map dust-obscured star formation and the cosmic baryon cycle down to pc-scales out to the Virgo cluster; take a cosmic census of the molecular gas which fuels star formation back to first light and cosmic reionization; and carry out novel techniques for exploring temporal phenomena from milliseconds to years. The ngVLA is optimized for observations at wavelengths between the superb performance of ALMA at submm wavelengths, and the future SKA-1 at few centimeter and longer wavelengths, thus lending itself to be highly synergistic with these facilities. In this talk I will briefly describe the current status of ngVLA community effort, while highlighting a number of the tranformative science cases that are driving the design of the ngVLA.

Satyakumar Nagarajan (The Ohio State University)

James P McMillan (The Ohio State University)
Christopher F Neese (The Ohio State University)
Frank C De Lucia (The Ohio State University)
Andrew M Burkhardt (University of Virginia)
Anthony Remijan (NRAO)

Rounding up the Weeds in the Astrophysical Garden

Individual spectral lines in astrophysical data are ordinarily assigned by comparison with line frequency and intensities predicted by catalogs. Here we have fit the spectra of specific molecular sources within Orion KL that are present in the ALMA data. For each molecule in this study, reference lines are selected and then fit to determine a temperature and column density for each velocity class. These column densities and temperatures are used in conjunction with our complete experimentally measured spectra [8] to model each molecules contribution to the entire astrophysical spectrum. Effects due to optical thickness and spectral overlap are included in the analyses. We will present our results on ethyl cyanide, vinyl cyanide, and methyl cyanide in Orion KL.

[8]McMillan, J.P., Fortman, S.M. , Neese, C.F. and De Lucia, F.C., The Complete, Temperature Resolved Experimental Spectrum of Methanol (CH_3OH) between 214.6 and 265.4 GHz, 2014, *ApJ*, **795**, 56

Kouichiro Nakanishi (National Astronomical Observatory of Japan)

Naomasa Nakai (Univ of Tsukuba)
Nario Kuno (Univ of Tsukuba)
Kotaro Kohno (Univ of Tokyo)
Ryo Ando (Univ of Tokyo)
Kazuo Sorai (Hokkaido Univ)

Dense Ionized Gas Embedded with Infant Massive Stellar Clusters in the NGC 253 Nuclear Starburst

Massive stellar cluster is a major site of galaxy nuclear starburst, and the properties of it are supposed to be consistent with the idea that it is a progenitor of globular clusters. The birth and infancy of massive stellar cluster are of great interest, and mm/sub-mm recombination line observation is the optimal way to gain insight into them. Mm/sub-mm recombination line suffers little interstellar extinction, and the property makes it the most effective means of unveiling dense ionized gas and infant massive stellar clusters which are deeply embedded in natal interstellar matter.

ALMA observations of hydrogen recombination line (H30α) toward a nearby starburst galaxy NGC 253 were carried out with unprecedented high spatial resolution (10 pc). The emission in the nuclear starburst region is resolved into compact sources. By combining with archival data of millimeter wave continuum emission, electron density and emission measure of them are estimated, and they turn out to be similar to or even higher than those of Compact and Ultracompact HII regions in the Milky Way Galaxy. The recombination line and continuum emission fluxes indicate that each source contains up to a few hundred of O-type stars, and this suggests the sources are dense ionized gas clumps embedded with aborning and/or infant super stellar clusters.

Kin-Wang Ng (Academia Sinica)

Kin-Wang Ng

Galaxy Clusters in Clustering and Non-Clustering Dark Energy Models

We use the spherical collapse model to study the evolution of the over-density large scale structures in clustering and non-clustering dark energy models. We are able to categorize the physical quantities of the low- and high-redshift galaxy clusters for a given dark energy model. We show that galaxy clusters are formed differently from the standard Lambda cold dark matter model. This will affect the prediction for the cluster masses, the cluster abundances, the weak gravitational lensing, and etc in different dark energy models.

Lars-Ake Nyman (JAO)

et al

Spectral Line Surveys of Carbon-Rich Circumstellar Envelopes in the 3-mm Band

Much of our knowledge about molecular line emission from carbon-rich circumstellar envelopes and circumstellar chemistry is based on the results obtained for a single object, the nearby, high-mass-loss-rate carbon star IRC+10216, which is well-studied, both in single-dish and interferometry observations (Cernicharo et al. 2013; Cernicharo et al 2015; Decin et al, 2015). We have recently received ALMA data on a project to determine similarities and differences between the chemistry and morphology of the carbon-rich circumstellar envelopes of IRAS 07454-7112, IRAS 15082-4808 and IRAS 15194-5115, and to compare them to the characteristics of the envelope of IRC+10216. The sources were selected based on their high luminosities, relatively high mass loss rates and the results from single dish spectral surveys by Woods et al. (2003), Nyman et al. (1993) and Smith et al., (2015), demonstrating that they are rich in molecular lines. The ALMA observations include spectral line surveys in the 3 mm band of the three objects. The poster will show the first results of the data analysis.

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Vivien Chen (National Tsing Hua University)
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Qizhou Zhang (1Harvard-Smithsonian Center for Astrophysics)
Gemma Busquet (Institut de Ciencies de l Espai)
Fumitaka Nakamura (National Astronomical Observatory of Japan)

Dense Core Properties in the Infrared Dark Cloud G14.225-0.506 Revealed by ALMA

We have carried out a dense core survey toward the Infrared Dark Cloud, G14.225-0.506, at 3 mm continuum emission with ALMA. This survey covers the two hub-filament systems and their associated filaments with a high angular resolution of $\sim$ 3". We identified 48 dense cores with mass in the range of 1.1 to 78 $M_{\odot}$ with clumpfind method. Sixteen out of the 48 cores are protostellar and associated with young stellar objects (YSOs), while the other 32 cores are not associated with known YSOs. Using the APEX 870 μm continuum data, we also identified 18 clumps hosting these cores. Through virial analysis using the ALMA N_2H^+ and VLA/Effelsberg NH_3 molecular line data, we find a decreasing trend in the virial parameter with decreasing scales from filaments to clumps, and then to cores. The virial parameters of $0.1 - 1.3$ in cores, indicate that the internal support is insufficient and that the cores are under dynamical collapse. We also found that the cumulative Core Mass Function (CMF) for the prestellar cores has a power law index of $\alpha = 1.1$, suggesting that the CMF has similar slope to the Salpeter Initial Mass Function (IMF). In contrast, Povich & Whitney (2010) show that the YSOs mass function is steeper ($\alpha = 3.2$), indicating a deficit of high-mass YSOs in the region. To make up such a deficit, high-mass stars should be formed in the prestellar cores by accreting a significant amount of the surrounding gas in future. Another possibility is that low-mass protostars are grown in protostellar cores fed by connecting filaments and become massive stars.

Kyoko Onishi (SOKENDAI The Graduate University for Advanced Studies)

Timothy Davis (Cardiff University)
Martin Bureau (University of Oxford)
Michele Cappellari (University of Oxford)
Satoru Iguchi (National Astronomical Observatory of Japan)
Marc Sarzi (University of Hertfordshire)

WISDOM: Supermassive Black Hole Mass Measurements in nearby galaxies

Using molecular gas kinematics, we measure the supermassive black hole (SMBH) mass in nearby galaxies observed with CARMA and ALMA. The masses are measured to good accuracy ($\sim 20\%$ error), and follow the M-sigma relation. We show our new fitting method to interferometric data (3D) that determines molecular gas disk profiles in addition to mass distribution parameters. Unlike other direct SMBH mass measurement techniques, molecular gas kinematics is applicable to all galaxy types. This relatively new method will bring large sample that allows detailed studies of the M-sigma relation, and will eventually shed light on the co-evolution of galaxies and SMBHs.

Mayra Osorio (Instituto de Astrofisica de Andalucia CSIC Spain)

Enrique Macias (Instituto de Astrofisica de Andalucia CSIC Spain)
Guillem Anglada (Instituto de Astrofisica de Andalucia CSIC Spain)
Carlos Carrasco-Gonzalez (Instituto de Radioastronom a y Astrofisica UNAM Mexico)
Roberto Galvan-Madrid Luis Zapata (Instituto de Radioastronom a y Astrofisica UNAM Mexico)
Nuria Calvet (Department of Astronomy University of Michigan USA)

ALMA Imaging of a Dwarf Protoplanetary Disk In XZ Tau B

We report the ALMA discovery of a tiny protoplanetary disk of dust around the young star XZ Tau B. The disk has a radius of only 3.4 au, and a central cavity of 1.3 au in radius that we attribute to clearing by a compact system of orbiting (proto)planets. The ALMA image and our modeling show that the disk presents all the features of a classical transitional disk, but on a much smaller scale. Given the very small radii involved, evolution is expected to proceed very quickly in this disk, with observable changes on timescales of a few months, and thus easy to monitor with observations in the near future. The diversity of planetary systems observed in the exoplanet surveys suggests that an equivalent diversity should be found in their progenitors; the protoplanetary disks. The detection of a dwarf disk in XZ Tau B suggests that this kind of disks could be the precursors of low-mass compact planetary systems such as those identified in the Kepler mission.

Niraj Pant (The Catholic University of America)

Tommy Wiklind (The Catholic University of America)

Evolution of the Interstellar Gas Fraction over Cosmic Time

Two fundamental questions regarding the formation and evolution of galaxies are how they acquire their gas content and how this is turned into stars. Observations at restframe optical wavelengths suggest that at z¿4 the gas accretion rate exceeds the star formation rate and the baryonic content is dominated by the interstellar gas. We currently have very limited observational data on the evolution of the gas and the star formation history of galaxies at z¿2. It is therefore of vital importance to establish the gas fraction in galaxies as a function of redshift. This is now possible with ALMA and we propose to observe a sample of galaxies at z 2,3,4 and 5, using dust continuum as a proxy for the interstellar gas. The sample selection is based on the multi-epoch abundance method which allows us to pick galaxies at different redshifts which are progenitors of a galaxy of fixed stellar mass at z=0. This type of selection is crucial for studying real evolutionary effects across cosmic time. The stellar mass of all galaxies in our sample is high enough to ensure that metallicity will not affect the dust-to-ISM conversion.

Jenny Patience (Arizona State)

K Ward-Duong (ASU)
G van der Plas (U Chile)
J Bulger (Subaru)
F Menard (IPAG)
C Pinte (IPAG)

Disk Sizes and Grain Growth Across the Stellar/Substellar Boundary

With a combination of submm/mm observations from ALMA, CSO, and PdBI, we are investigating the properties of disks around low mass stars and brown dwarfs in the Taurus star-forming region. Disk sizes and spectral slopes are important properties to assess the formation scenarios for brown dwarfs and the viability of planet formation in the disks. The ALMA maps have a beam size of approximately 0.3arcseconds and a number of the sources are spatially resolved in the continuum and CO(3-2) line measurements. For most of the resolved systems, the gas disks are more extended than the dust disks, similar to previous results from observations of more massive stars. From the multi-wavelength data, we are measuring the spectral slope of the emission to search for the signature of initial grain growth that is encoded in the slope of the spectral energy distribution in order to test the hypothesis of enhanced radial drift in disks around substellar objects. Theoretical studies have suggested that fast radial drift could prevent the growth of dust particles up to large bodies in brown dwarf disks, and our program is designed to obtain a set of measurements for objects across the stellar/substellar transition.

D Kala Perkins (GTU UC Berkeley)

The Universe Isn't Silent: Electroacoustic Ensembles with Cosmic Symphonics

The universe isn't silent. It has a sound track and that sound track is played on space itself, because space can wabble like a drum; it can ring out a kind of recording throughout the universe of some of the most dramatic events as they unfold. We are adding to our glorious light understanding of the universe, a sonic composition. (Jana Levin)

The ALMA Soundbank transposes chords from the skies into sound files for musical composing. (NRAO)

LIGO (ground based) and LISA (space based) gravitational wave observatories are listening to the universe for the ringing wabble of gravitational waves in space as it squeezes and stretches from colliding black holes. We now have transposed sound files of our first collision data. The use of radio waves translated into sound are being used both by research astrophysics in the quest to detect new distant planetary orbits with Kepler Space Telescope data, as well as at the convening of cosmos and culture. A software program called xSonify is allowing a blind astronomer to study data, as well as to assist sighted astronomers to discern patterns more readily accessible to the ear than by sight. Dr. Fiorella Terenzi (astrophysicist and composer) has developed what she calls Acoustic Astronomy translating actual astronomical data, particularly from radio sources into compositions to both inform and inspire. Astronomers are sonifying the data from the cosmic microware background and pulsars to better understand the rhythmic and harmonic principles of our universe. ALMA is at the forefront of this cosmic compositional investigation having developed a public archived data soundbank, transposing the sounds from the EM chords of spatial data. Using innovative technologies to give artists and musicians access to astronomical resources, they now have over 3200 registered user participants and have presented at several festivals, bring science and art into creative convergences. This presentation will explore these creative dialogues emerging from our shared resonant immersion in cosmos symphonic encounters.

Dom Pesce (University of Virginia NRAO)

J A Braatz (NRAO)
C M V Impellizzeri (NRAO)
J J Condon (NRAO)
F Gao (NRAO SHAO)
J E Greene (Princeton University)

Submillimeter Water Megamasers in Nearby AGNs

With the sensitivity and spatial resolution of ALMA, detailed studies of sub-mm water megamasers in AGNs are possible for the first time. Observations of these megamasers will complement and expand on the rich observations of 22 GHz systems that have, until now, provided the only means to map molecular gas in AGNs directly on sub-pc scales. In this work, we have used a combination of Cycle 0 archival data and Cycle 2 observations to explore sub-mm masers in three AGNs previously known to host strong 22 GHz megamaser activity: NGC 4945, Circinus, and ESO 558-G009. We present the first detections of 321 GHz megamaser activity in NGC 4945 and ESO 558-G009, and in the latter case the masers are tentatively associated with the circumnuclear accretion disk. For Circinus, our updated analysis of the sub-mm maser system indicates that although the 321 GHz masers inhabit approximately the same gas as the 22 GHz masers, they may also trace the accretion disk at radii interior to their 22 GHz counterparts. Future long-baseline observations of this maser system will spatially resolve the maser distribution. If they can be widely detected, observations of these and other sub-mm lines will greatly increase the power of megamasers to measure black hole masses, distances, and physical conditions in accretion disks.

Richard Plambeck (U C Berkeley)

Melvyn Wright (U C Berkeley)

ALMA Observations of Orion Source I at 353 and 662 GHz

Orion Source I is the protostar at the heart of the Kleinmann-Low Nebula. ALMA observations of Source I were made at 350 and 660 GHz with 0.2 arcsec angular resolution to search for the H26alpha and H21alpha radio recombination lines, and to measure the continuum flux densities. Neither radio recombination line was detected, ruling out the possibility that the source is a hypercompact HII region. The continuum spectrum of Source I from 43 to 650 GHz can best be understood as optically thick thermal emission from 650 K dust in an edge-on, 100 AU diameter toroid or disk. We estimate that the disk mass is in the range 0.02 to 0.2 Mo.

A rich spectrum of molecular emission lines is detected from the disk, mostly from sulfur- and silicon-rich molecules such as SO, SO2, and SiS, but also including vibrationally excited CO and several unidentified transitions; upper state energy levels are mostly in the range 500-2000 K. Spectral lines show a clear velocity gradient along the major axis of the disk, consistent with rotation around a 5-7 Mo central object. A central mass of less than 10 Mo and the existence of a 100 AU diameter disk are incompatible with the popular model in which Source I and the nearby Becklin-Neugebauer Object, a B star, are recoiling from one another following their ejection from a multiple system.

Ramprasad Rao (ASIAA)

JM Girart (CSIC-IEEC)
ZY Li (U Virginia)

Does Polarization from Scattering Contaminate Magnetic Field Observations in Star Forming Regions?

In recent years, polarized emission from aligned dust grains have been used to successfully probe the structure of the magnetic field in regions of star formation. This technique was used to conduct polarization observations towards IRAS 16293B which is a young stellar object with an almost face on geometry. The SMA observations showed that the magnetic field had a toroidal or azimuthal ring like structure. Those observations were the basis of our ALMA Cycle 2 proposal which was observed in July 2015. The data which were recently delivered to us tell a different story. The observed polarization is in fact more consistent with that produced by scattering instead of from aligned dust emission and that this polarization arises from grain sizes which are roughly 200 micron in size. However, in order to confirm that, we need observations at a different wavelength. To this end, we have proposed Band 3 observations in Cycle 4 of this same object and with the same resolution of 0.2 arcseconds. At these longer wavelengths, we would expect less contribution from scattering and that the polarization produced will be dominated by emission from magnetically aligned dust grains. If on the other hand, scattering continues to be the dominant mechanism even at these longer wavelengths, then it would imply that the grain size distribution is much larger, i.e. grain sizes of up to 500 micron are present. This has significant impact on directly constraining the grain sizes via observations in protostellar disks. the grain sizes via observations in protostellar disks.

Jeonghee Rho (SETI Institute and SOFIA Science Center)

G Sandell (SOFIA Science Center USRA)
B-G Andersson (SOFIA Science Center USRA)
D Backman (SETI Institute SOFIA Science Center)
R Sankrit (SOFIA Science Center USRA)
H Zinnecker (DSI SOFIA Science Center)

SOFIA's Science Capabilities and Synergy with ALMA

NASA's SOFIA (the Stratospheric Observatory for Infrared Astronomy) is only airborne observatory for mid- and far-infrared astronomy, complementing submillimeter observations with ALMA. SOFIAś B747SP aircraft carries a 2.5-meter telescope designed to make sensitive mostly far-infrared observations from above most of Earthś atmospheric water vapor. SOFIA has detected molecules including high-J CO, OH, H2D+, OD and SH, HDO and H20, as well as the important fine structure cooling lines [C II] and [O I]. SOFIA provides spectroscopy with high spectral resolution in the FIR (60 – 200 micron) and mid-IR (5 - 28 micron), i.e. wavelength regions that ALMA cannot observe. The FIR wavelength regime favors light molecules (hydrides), while the mid-IR gives access to ro-vibrational lines. We highlight SOFIAś science results and synergies with ALMA.

Examples include CO and water lines. SOFIA follow-up observations in high-J CO lines and ground-state water lines can be made for various astronomical objects (protostars, photodissociation regions, the interstellar medium and solar systems planets). For example, high-J lines of CO(16-15), CO(13-12), and CO(12-11) are detected from the Cep E protostellar outflow with SOFIA/GREAT. The high J-CO lines trace warm gas from the recent impact of the protostellar jet into the ambient cloud, producing a non-stationary magnetized shock, which drives the formation of an outflow cavity. ALMA instead can observe low-J CO lines in molecular outflows at high spatial resolution. SOFIAś water detections have been made from the base of the envelope of the high-mass protostars AFGL 2591 and also water and deuterated water abundances have been mapped over the Martian disk (to measure the D/H ratio), using the high-resolution mid-infrared spectrograph EXES. EXES detected ten absorption features of water emission between 6.086 and 6.135 micron toward AFGL 2591, and also H20 and HDO lines near 7.2 micron from Mars. ALMA band 5 observations of the 183 GHz water line could complement these SOFIA observations.

We will summarize SOFIAś capabilities with the existing instruments GREAT/upGREAT, FIFI-LS, EXES, FORCAST, FLITECAM, HIPO/FPI+ and HAWC+, and the potential two instruments being considered in the 3rd Generation NASA instrument call.

Luca Ricci (Harvard-Smithsonian Center for Astrophysics)

ALMA Observations of Disks Around Young Low-Mass Brown Dwarfs and Planetary Mass Objects

ALMA observations of young protoplanetary disks have already revolutionized our view of planet formation. The unprecedented sensitivity of ALMA allows us to study in detail for the first time the physical conditions of disks expected around very low mass objects, such as low-mass brown dwarfs and planetary mass companions. I will present the results of new ALMA observations of disks around young, nearby low-mass brown dwarfs and planetary-mass objects. The detection of CO from a low-mass brown dwarf disk allowed us to get the first dynamical estimate for the mass of a single young brown dwarf from the disk kinematics. This provides an important test for models of young brown dwarfs which predict masses from the inferred luminosity and effective temperature. The sub-Lunar upper limit derived for the dust content in the disk surrounding the 2M1207b planetary-mass companion has important implications for the formation models of giant planet and of their satellites.

Dominik Riechers (Cornell University)

Chris Carilli (NRAO)
Peter Capak (IPAC)
Nick Scoville (Caltech)
Riccardo Pavesi (Cornell)
Vernesa Smolcic (U Zagreb)

An Extremely Compact, Warm, Optically Thick Nucleus in a Massive Dusty Starburst Galaxy in the First Billion Years of Cosmic Time

Over the past five years, ALMA has revolutionized studies of the interstellar medium and dust-obscured star formation in high-redshift galaxies, resulting in a vastly improved picture of the physical properties and chemical composition of the gas and dust in galaxies in the early universe. We here present unprecedented new observations that demonstrate ALMA's most recent new capabilities by spatially and dynamically resolving an unlensed, massive dusty "maximum starburst" galaxy at redshift 5.3 with a star formation rate of 1100 Msun/yr down to <250pc (<40 milli-arcsecond) scales. These data show that ∼15% of the enormous star formation activity in this system emerge from an unresolved, compact, warm, optically-thick nucleus with high gas excitation within the <2.5kpc diameter dust-emitting starburst region. The star formation rate surface density in this core region exceeds the Eddington limit for radiation pressure-supported starburst disks, but its gas depletion timescale is extremely short. This may suggest that this system is undergoing a brief peak phase in its activity, near the onset of strong atomic and molecular outflows - a key stage in the early evolution of massive galaxies.

Julio Rodriguez (UCLA)

Mark R Morris (UCLA)
Elisabeth Mills (San Jose State University)
Sergio Mart n (Joint ALMA Observatory Alonso de Co rdova 3107 Vitacura Santiago)
Hauyu Baobab Liu (Academia Sinica Institute of Astronomy and Astrophysics)
Jun-Hui Zhao (Harvard-Smithsonian Center for Astrophysics)

A Radio Recombination Line Study of Sgr A West with ALMA

We present and analyze radio recombination line (RRL) images obtained with ALMA toward the HII region Sgr A West, which surrounds the supermassive black hole at the Galactic Center. This investigation is part of a larger project to investigate the molecular Circumnuclear Disk that largely circumscribes Sgr A West. Using RRLs in band 3 (H40, H41, and H42) and band 6 (H29), we have analyzed a number of important dynamical features, including the Northern Arm, the Western Arc, the Eastern Arm and itś apparent continuation as the Bar, as well as the linear East-West Ridge that crosses the Northern Arm in projection. At the spatial resolution available to ALMA in the H29 line (1.34 x 0.95), several of these features are found to be separable in the position-velocity data cubes into quasi-linear substructures. In addition to presenting the velocity fields of various features and discussing their dynamics and continuity, we also compare the RRL images to simultaneously obtained molecular line maps to locate the ionization fronts in Sgr A West.

Matus Rybak (Max Planck Institute for Astrophysics)

Simona Vegetti (MPA Garching)
John P McKean (Kapteyn Institute Groningen ASTRON)
Paola Andreani (ESO Garching)
Simon D M White (MPA Garching)

Strong Gravitational Lensing and ALMA: Revealing the Nature of High-Redshift Galaxy SDP.81

Dusty star-forming galaxies at redshiftsz=2-5 are main drivers of the epoch of the most intense star formation in the history of the Universe, and hence crucial for our understanding of the galaxy formation. However, the study of these objects has so far been limited to kiloparsec scales, providing only a limited glimpse into their morphology and physical conditions. Although these galaxies are too faint and compact to be resolved in any detail even with ALMA, strong lensing provides a flux magnification boost by a factor of about 10-20, pushing the resolution limit by more than an order of magnitude.

In this talk, I will present a novel visibility-fitting Bayesian lens modelling technique for the reconstruction of the properties of high-redshift lensed galaxies; I will then present a recent application to the ALMA Long Baseline Campaign observations of a strongly lensed star-forming galaxy SDP.81, and results of spectral synthesis modelling of ISM conditions in SDP.81 and search for massive substructure in the lensing galaxy. In particular, I will show how by reconstructing the structure of source-plane sub-mm continuum and CO line emission region on sub-100-pc scales and in combination with HST and VLA imaging, we are, for the first time, able to resolve ISM conditions in a z=3 galaxy in an unprecedented detail, demonstrating the potential of strong lensing with ALMA for detailed studies of high-redshift galaxies.

Mahya Sadaghiani (University of Cologne)

Mahya Sadaghiani (University of Cologne)
Alvaro Sanchez-Monge (University of Cologne)
Peter Schilke (University of Cologne)
Riccardo Cesaroni (INAF-Arcetri Astrophysical Observatory Italiano IT)

High Resolution Observations of the Hot Core In G29.96-0.02

The details of physical processes through which the hot O and B stars form is still an unsolved problem in astrophysics. The key problem is that the radiation pressure from the high-mass protostars is high enough to stop the mass accretion. The existence of a circumstellar disk around O-type protostars can solve the so-called radiation-pressure problem and clarify the formation of massive stars via the disk-outflow systems. We present high angular resolution observations obtained with the Atacama Large Millimeter/submillimeter Array toward the hot core in G29.96-0.02. By searching for optically thin disk tracers like CH3CN isotopologues and some other promising molecules like CH3OH, we can trace rotation around the massive stars. In order to prove the presence of a disk, we need to look for velocity gradient and check if the direction of the gradient is perpendicular to outflow associated with the disk. Therefore, it is necessary to produce the velocity and column density maps using XCLASS in addition to line analysis. XCLASS is a toolbox for CASA, developed at the University of Cologne and aims at identifying and fitting spectral lines. By taking advantage of XCLASS, it is possible to fit the spectra on a pixel-to-pixel basis for a data cube to extract information on the column density, temperature and velocity. Consequently, by repeating this process for all of the pixels it is possible to get map of these three physical parameters. Then, we can verify how the velocity-position plots of the tracers behave along the plane of the disk. XCLASS is able to minimize the blending problem by fitting all species and their components at once. It is assumed that LTE condition is valid for the most molecules.

Kazuya Saigo (Osaka Prefecture University)

Kazuya Saigo (Osaka Prefecture University)
Kohji Tomisaka (National Astronomical Observatory of Japan)
Nagayoshi Ohashi (National Astronomical Observatory of Japan)
Yusuke Aso (Tokyo University)
Shin Koyamatsu (Tokyo University)

Three Dimensional Kinematic Structure of L1527IRS Protostellar Outflow Revealed with ALMA

We present three dimensional kinematic structure of $C^{18}O$ dense molecular outflow of L1527IRS. It is believed that the protostellar molecular outflow is a key process in star formation. Protostellar outflow is directly related to the mass/angular momentum accretion onto the central protostellar system. In addition, it may cause the dispersal of parent cloud core. We observed L1527IRS by ALMA Band 6 in Cycle 0/1 phases in order to reveal the kinematic structure of protostellar envelope and disk. L1527IRS is well known near-by Class 0/I borderline object and has observed extensively from radio wavelength to Near-IR. Our results show that 1. $C^{18}O$ outflows of L1527IRS are launched with very large opening angle (~160 deg at $R = 500$ AU). It is almost along the cavity structure seen in IR scattering light (see Tobin et al. 2008). 2. $C^{18}O$ outflows of L1527IRS are accelerated with the power-law index of $\sim$ 1.3 over 1500 AU scale (from ~0 km/s to 4 km/s). 3. Specific angular momentum of $C^{18}O$ outflow is much smaller than that of the infalling envelope. These results suggest that $C^{18}O$ outflows of L1527IRS are less collimated MHD disk wind or the interaction layer between higher velocity outflow/wind and the dense gas envelope.

Toshiki Saito (University of Tokyo)

Daisuke Iono (NAOJ SOKENDAI)
Min Yun (UMass Amherst)
Kouichiro Nakanishi (NAOJ SOKENDAI)
Junko Ueda (CfA)
Daniel Espada (JAO)

Revealing Physical, Chemical, and Morphological Structure of the Luminous Infrared Galaxy VV 114 with ALMA

We present bands 3/4 (1”.0 $\sim$ 400 pc) spectral scan and band 7 high-resolution (0″.2 $\sim$ 80 pc) observations toward the nearby luminous merging galaxy VV 114. Our line survey revealed that the “overlap” region, which is located between the progenitor’s galaxies, is rich in molecular lines compared with their nuclei. We detected multiple CH_3OH and HNCO transitions only at the overlap, indicating the presence of gas-phase shocks. We also identified a compact ($<$ 80 pc), broad ($\sim$ 300 km s^{-1}) dense gas core at the eastern galaxy. Because of its large dynamical mass and hard X-ray detection, we suggest the presence of an AGN. These AGN, overlap region, and other star-forming dense clumps are found to form a single narrow filament of gas and dust ($\sim$ 4 kpc) connecting the progenitor’s disks. Its structure is consistent with that predicted by numerical simulations of a major merger. The VV 114 is an ideal system which allows us to investigate physical/chemical conditions of AGN, nuclear/extended starbursts, merger-induced shock, and possible connection among them simultaneously.

Goran Sandell (SOFIA-USRA)

B Mookerjea (Tata Institute Mumbai India)
M Wright (UC Berkeley USA)

The Ionized Jet and Molecular Outflow from NGC7538 IRS1

The young heavily accreting ultra-compact HII region NGC7538 IRS1 is known to drive a well collimated bipolar ionized jet approximately north south. Yet most studies have reported that it drives a bipolar molecular outflow oriented from south east (red-shifted) to north west (blue-shifted). Precession has been suggested as an explanation of why the ionized and molecular outflows are misaligned. New [CII] 158 micron and CO(11-10) maps obtained with GREAT on SOFIA combined with mm-data from OSO, FCRAO, JCMT, BIMA, and CARMA as well as mid-IR images from SPITZER show that all the observed characteristics of NGC7538 IRS1 can be explained by a large (parsec scale) north-south outflow, possible rotating.

Patricio Sanhueza (NAOJ Chile Observatory)

A Survey of Prestellar, High-Mass Cluster-Forming Clumps: Constraining Models of High-Mass Star Formation

In order to characterize the earliest stages of high-mass star formation and constrain theoretical models, we have carried out a survey of prestellar, high-mass cluster-forming clumps at 1.3 mm with ALMA. We have made 10-pointings mosaics with the 12 m array, in addition to ACA and total power, to fully cover 12 cold, massive 70 μm dark clumps from the MALT90 survey. In addition to dust continuum emission, 10 molecular lines are included in the spectral setup. Here, we present preliminary results on 4 clumps in only the dust continuum emission observed with the 12 m array. Clumps have from 10 to 26 cores above 5σ (total of 67 cores). Masses range from 0.4 to 9 $M_{\odot}$. Massive, compact cores (>30 $M_{\odot}$, <0.1 pc) are not detected. However, to correctly assess the existence of high-mass prestellar cores the 12 m data needs to be combined with the ACA. The 4 clumps presented here show a lack of distributed low-mass cores, considering that the cluster-forming clumps have $\sim$1,000 $M_{\odot}$ and should form stellar clusters containing high-mass stars.

Tsuyoshi Sawada (JAO NAOJ)

Tetsuo Hasegawa (NAOJ)
Jin Koda (Stony Brook University)

Internal Structures of Molecular Clouds in the LMC Revealed by High-Fidelity Imaging with ALMA

We observed five giant molecular clouds (GMCs) in the Large Magellanic Cloud (LMC) using ALMA. The high-fidelity 12CO J=1-0 images with a high spatial resolution (0.5 pc) reveal a variety of internal structures of the gas, from spatially-extended faint emission to compact bright structures. This ALMA study is motivated by our earlier results in the Milky Way (Sawada et al. 2012a, 2012b), where we found a variety of structures along cloud evolutionary phase and suggested that the internal structures develop as clouds evolve. Two of our sample clouds in the LMC have associated massive star formation (Kawamura et al. 2009) and show very complex structures with clumps and filaments. The other three have very similar masses to each other and are not associated with massive star formation; however their s̈tructurednessäre quite different. We discuss the relationship of the internal structures of molecular gas with star-forming activities and environment.

Nathan A Seifert (University of Alberta)

Anthony Remijan (NRAO)
Brett A McGuire (NRAO)

Splatalogue, the Database for Astronomical Spectroscopy: Updates and Plans for ALMA Full Science Operations

Over the last decade, Splatalogue has provided the radio astronomical community with a constantly updated, collated resource of spectroscopic data for atomic and molecular species. Since its inception, Splatalogue has included the complete spectroscopic catalogues from sources such as JPL and the Cologne Database for Molecular Spectroscopy (CDMS), as well other as the Lovas/NIST recommended rest frequency database and other members of the spectroscopic community.

Recently, in preparation for the transition into full science operations at ALMA, a number of improvements and updates to Splatalogue have been undertaken to provide enhanced support for relevant research efforts. These improvements include a complete update of the JPL and CDMS linelist archives to the most recently available data, improvements to the legacy Lovas/NIST catalogue with new NRAO recommended rest frequencies and indexing of astronomical source and survey citation information for recommended transitions that have been reported as astronomically detected in the literature. Additionally, a number of quality of life features requested by Splatalogue users have been added to the Splatalogue website.

Finally, although these efforts have been made to support Splatalogue development over the next decade, it is not without the constant input of the astronomical community that targeted improvements to both quality of life and data integrity could be made, and any input or suggestions from the greater scientific community are welcome.

Patrick Sheehan (University of Arizona)

Josh Eisner (University of Arizona)

Disk Masses of Class I Protostars in Taurus and Ophiuchus

Recent studies suggest that many protoplanetary disks around 1-5 Myr old pre-main sequence stars contain insufficient mass to form giant planets. This may be because by this stage much of the material in the disk has already grown into larger bodies, hiding the material from sight. To test this hypothesis, we have observed every protostar in Taurus and Ophiuchus identified as Class I in multiple independent surveys, whose young (¡ 1 Myr old) disks are more likely to represent the initial mass budget of protoplanetary disks. Using detailed radiative transfer modeling of CARMA and ALMA data, we determine the geometry of the circumstellar material and measure the mass of the disks around these protostars. By comparing the inferred disk mass distribution with results for the existing 1-5 Myr old disk sample, we constrain the initial mass budget for forming planets in protoplanetary disks.

Andrea Silva (NAOJ Tufts University)

Anna Sajina (Tufts University)
Carol Lonsdale (NRAO)
Mark Lacy (NRAO)

ALMA Detected Overdensity of Sub-Millimeter Sources Around WISE/NVSS-Selected z 2 Dusty Quasars

We study the environments of 49 *WISE*/NVSS-selected hyper-luminous, heavily obscured, z$\sim$2 quasars using the ALMA in Band 7 (345 GHz). We find that 17 of the 49 *WISE*/NVSS sources show additional sub-mm galaxies within the ALMA primary beam which, probing scales within $\sim 150\,$kpc. We find a total of 23 additional sub-millimeter sources, four of which are in the field of a single *WISE*/NVSS source. The measured 870 μm source counts are $\sim$10$\times$ what is expected for unbiased regions, suggesting such hyper-luminous dusty quasars are excellent at probing high-density peaks.

Kazimierz Sliwa (MPIA Heidelberg)

Eva Schinnerer (MPIA)
Annie Hughes (Universit de Toulouse)
Kathryn Kreckel (MPIA)
Adam Leroy (OSU)
SFNG Team

Cloud Scale View of Spiral Galaxies: First Results from the Nearby Galaxy M74

ALMA can provide an unprecedented view onto the molecular gas across the galactic environment present in nearby star forming disk galaxies. Here, we present first results from the local (D=7.2 Mpc) face-on grand-design spiral galaxy M74 (NGC 628) that we have mapped during Cycle 1/2 in 12CO(2-1) plus 12CO and 13CO(1-0) at high (1-2") resolution covering the inner 240" x 150" (8.4 kpc x 5.3 kpc) region. Comparison to other galaxies with similar data at Giant Molecular Cloud (GMC) resolution shows that the shape of GMC mass functions is a strong function of galactic environment. Our novel method to link small-scale molecular gas properties finds significant variation in these properties across galaxies. Finally, we combine our ALMA data for M74 with MUSE observations of HII regions at a similar spatial resolution to study the Kennicutt-Schmidt star formation law at the scale relevant to the physics of star formation.

Sabrina Stierwalt (NRAO)

Kelsey Johnson (University of Virginia)
David Patton (Trent University)
Gurtina Besla (University of Arizona)
Nitya Kallivayalil (University of Virginia)
Mary Putman (Columbia University)

The Star Forming Main Sequence at Low Galaxy Mass

We present an investigation of the star-forming main sequence at the low mass end. The relation between galaxy stellar mass and star formation rate has been well-studied in the recent literature for a range of redshifts and galaxy type, but almost all of these studies are limited to galaxies with stellar masses above the dwarf galaxy range (10^9 Msun). Our work, based on the panchromatic TiNy Titans survey of interacting dwarf galaxies, shows that dwarf galaxies extend the well-established main sequence at z=0 down to lower masses. Furthermore, like their more massive counterparts, dwarf mergers appear on an elevated main sequence with higher star formation rates for a given stellar mass. Finally we show that star formation is enhanced to a greater extent in low mass galaxy mergers than for higher mass systems.

Michael Stroh (University of New Mexico)

Ylva Pihlstrom (University of New Mexico)
Lorant Sjourman (NRAO)
Michael Rich (UCLA)
Mark Morris (UCLA)
Mark Claussen (NRAO)

The Bulge Asymmetries and Dynamic Evolution (BAaDE) ALMA Pipeline

The Bulge Asymmetries and Dynamic Evolution (BAaDE) project aims to construct a sample of at least 20,000 SiO maser stars located primarily in the inner Galaxy. This sample will provide tracers of the dynamics in this region. The SiO maser stars are detected via observations at 43 and 86 GHz, using both ALMA and the VLA. Typically, such observations use frequent scans on phase calibrators between target scans. Since the BAaDE project's aim is search 35,000 SiO maser candidates, a normal observing strategy therefore requires a heavy overhead in calibrator time. In this presentation we discuss how the observing time can greatly be reduced if the SiO masers themselves can be used as calibrators. SiO masers with typical peak fluxes of a couple hundred mJy are easily detected after tens of seconds of observing, allowing for self-calibration within short scans, and our high detection rate ($> 50\%$) results in nearly every other source being used for self-calibration. Here we present details of our ALMA pipeline scripts applying this observing strategy developed for BAaDE, which eventually can be generalized for other projects with similar observing strategies.

Satoko Takahashi (JAO NAOJ)

Paul Ho (ASIAA EAO)
Josep-Miguel Girart (CSIC)
Kohji Tomisaka (NAOJ)
Masahiro Machida (Kyushu University)
Ed Fomalont (JAO NRAO)

Role of the Magnetic Field in ≤ 100 AU: New Insights on Star Formation Revealed with ALMA

With the longest baseline available in ALMA Cycle 3, we have performed linear polarization observations in 1.1mm continuum emission toward a candidate of the youngest intermediate mass protostellar source embedded within the Orion Molecular Cloud. We have achieved the spatial angular resolution of $0''.03 \times 0''.02$ that corresponds to the linear size scale of ≈10 AU at the distance to the source. We have revealed great details of the spatial structures of linearly polarized emission and their vectors within central 300 AU. Our results show some characteristic structures in both Stokes I and linearly polarized emission, suggesting a connection between the magnetic field structures and the material distribution. In the poster, we will present images obtained from our experiments and make comparison with the recent MHD and hydro dynamic simulations in order to constrain the geometrical structure of the magnetic field.

Ken'ichi Tatematsu (National Astronomical Observatory of Japan)

Ken'ichi Tatematsu (National Astronomical Observatory of Japan)
Satoshi Ohashi (University of Tokyo)
Patricio Sanhueza (National Astronomical Observatory of Japan)
Quang Nguyen Luong (National Astronomical Observatory of Japan)
Tomofumi Umemoto (National Astronomical Observatory of Japan)

Angular Momentum of the N_2H^+ Cores in the Orion A Cloud

We have analyzed the angular momentum of the molecular cloud cores in the Orion A giant molecular cloud observed in the N_2H^+ $J = 1 \rightarrow 0$ line with the Nobeyama 45 m radio telescope. We have measured the velocity gradient using position velocity diagrams passing through core centers, and made sinusoidal fitting against the position angle. 27 out of 34 N_2H^+ cores allowed us to measure the velocity gradient without serious confusion. The derived velocity gradient ranges from 0.5 to 7.8 km s^{-1} pc^{-1}. We marginally found that the specific angular momentum J/M (against the core radius R) of the Orion N_2H^+ cores tends to be systematically larger than that of molecular cloud cores in cold dark clouds obtained by Goodman et al., in the $J/M - R$ relation. The ratio β of rotational to gravitational energy is derived to be $\beta = 10^{-2.3\pm0.7}$, and is similar to that obtained for cold dark cloud cores in a consistent definition. The large-scale rotation of the $\int$-shaped filament of the Orion A giant molecular cloud does not likely govern the core rotation at smaller scales.

Susan Terebey (Cal State LA)

Lizxandra Flores-Rivera (Cal State LA)
Karen Willacy (Jet Propulsion Laboratory)

Modeling Protostar Envelopes and Disks with ALMA

Thermal continuum emission from protostars comes from both the envelope and circumstellar disk. The dust emits on a variety of spatial scales, ranging from sub-arcseconds for disks to roughly 10 arcseconds for envelopes for nearby protostars. We present models of what ALMA should detect that incorporate a self-consistent collapse solution, radiative transfer, and realistic dust properties.

Kazuki Tokuda (Osaka Prefecture University)

Toshikazu Onish (Osaka Prefecture University)
Tomoaki Matsumoto (Hosei University)
Kazuya Saigo (Osaka Prefecture University)
Akiko Kawamura (National Astronomical Observatory of Japan)
Yasuo Fukui (Nagoya University)

ALMA Observations of a High-density Core, MC27/L1521F in Taurus: Dynamical Gas Interaction at the Possible Site of a Multiple Star Formation

We present the results of ALMA Cycle 0 and Cycle 1 observations in dust continuum emission and molecular rotational lines toward a dense core MC27 (a.k.a. L1521F) in Taurus, which is considered to be at very early stage of star formation. The Cycle 0 observations (Tokuda et el. 2014) revealed complex structures at the center. We found a few starless high-density cores, one of which (MMS-2) has a very high density of 10^7 cm^{-3}. A very compact bipolar outflow with a dynamical timescale of a few hundred years was found toward the protostar. The molecular line observation shows several cores associated with an arc-like structure whose length is 2000 AU, possibly due to the dynamical gas interaction (see also Matsumoto et al. 2015). Detailed column density distribution with the size from 100 to 10000 AU scale are revealed by combining the 12-m array data with the 7-m array data of the ALMA Compact (Morita) Array as well as with the single dish MAMBO data (Tokuda et al. 2016). Our analysis shows that the averaged radial column density distribution of the inner part (r $<$ 3000 AU) is N(H2)$\sim r^{-0.4}$, clearly flatter than that of the outer part, $\sim r^{-1.0}$. We are interpreting that the shallow slope of the radial profile of the density is probably not attributed to the inside-out collapse in the case of MC27/L1521F. A possible scenario is that the slope change is a consequence of a dynamical interaction between the high-density condensations and the envelopes because the inner part having the shallow slope overlaps with the region with the complex structures, such as arc-like structures we observed.

Adam Trapp (UCLA)

Michael Rich (UCLA)
Mark Morris (UCLA)

Milky Way Bulge SiO Masers

We present stellar SiO masers observed in the direction of the galactic bulge with ALMA (1,040 sources), and the JVLA (2,479 sources). These objects are selected by color from MSX, which has given an SiO detection rate of 70%. The presented sample, along with the 24,000 sources still being observed and reduced, provide extinction immune measurements of radial velocities of bulge stars. These maser stars are then compared with known galactic bulge samples such as APOGEE, BRAVA, and GIBS, as well as others, to determine if their positions overlap or are a separate population with their own substructure.

Catarina Ubach (NRAO)

Sarah Wood (NRAO)
Devaky Kunneriath (NRAO)
Andrew McNichols (NRAO)
Brian Kirk (NRAO)
Erica Keller (NRAO)

The Data Calibration/Imaging Blackbox

Every dataset obtained by ALMA (Atacama Large Millimeter/submillimeter Array) goes through a process of quality assurance (QA) before being ingested into the ALMA Science Archive and delivered to the PI. The QA process ensures that each ALMA dataset meets the standards agreed upon by the ALMA Regional Centers (ARC) at the beginning of each Cycle. The status of a dataset as it proceeds through its life-cycle has not always been immediately transparent to ALMA end-users. Here we shed some light on the standard procedures by which raw ALMA data are transformed into deliverable products for the projects supported by the North American ARC. We describe each stage of the QA conducted at the Joint ALMA Observatory and North American ARC before a dataset is delivered, including the life-cycle of a dataset not meeting the QA requirements.

Junko Ueda (Harvard-Smithsonian Center for Astrophysics)

Yoshimasa Watanabe (University of Tokyo)
Daisuke Iono (National Astronomical Observatory of Japan)
David J Wilner (Harvard-Smithsonian Center for Astrophysics)
Giovanni G Fazio (Harvard-Smithsonian Center for Astrophysics)
Satoshi Ohashi (University of Tokyo)

Mapping the Dense and Shocked Gas in the Nuclear Region of NGC 4038 (Antennae Galaxies)

It has been long predicted from numerical simulations that the presence of large-scale gas inflows leads to central gas accumulation and subsequent nuclear starburst activity in merging galaxies. We present 1" ($<$ 100 pc) resolution maps of five molecules (CN, HCN, HCO^+, CH_3OH, and HNCO) obtained with ALMA toward the 1 kpc nuclear region of NGC 4038, which is the northern galaxy of the mid-stage merger, Antennae galaxies. Three molecules (CN, CH_3OH, and HNCO) were detected for the first time in this region. High-resolution mapping reveals an offset between the central gas-rich region associated with the HCN (1–0) and CO (3-2) peaks and active star forming regions identified by the 3 mm and 850 mum emission. We also find that the CN (1–0)/HCN (1–0) line ratios are enhanced (CN/HCN $>$ 1) in the star forming regions, indicating the presence of the Photo-Dominated Region. The spatially widespread shocked gas traced in the CH_3OH and HNCO emission indicates sub-kpc scale molecular shocks close to the central massive molecular complex. We suggest that the molecular shocks may be caused by collisions between an inflowing gas and the central molecular complex.

Kenta Uehara (The University of Tokyo)

Masato Tsuboi (ISAS JAXA)
Yoshimi Kitamura (ISAS JAXA)
Ryosuke Miyawaki (J F Oberlin Univ)
Atsushi Miyazaki (NAOJ JSF)

Filamentary Structures of the Galactic Center 50km/s Molecular Cloud with ALMA

Recently Herschel survey observations have been revealed that the molecular clouds ubiquitously exist as a bundle of molecular filaments in the Galactic disk region irrespective of star formation activity. The widths of these molecular filaments are always 0.1 pc even though the column H2 densities vary by 1 or more order of magnitude ($10^{20-23}/\mathrm{cm}^2$). Additionally, because dense molecular cores have been found along with the filamentary structures of which column densities are more than $10^{22}/\mathrm{cm}^2$, it is probable that the molecular filament related to the star formation closely in the Galactic disk region. The physical properties of the molecular cloud in the Central Molecular Zone (CMZ) of the Galactic Center (GC) are quite different from those in the Galactic disk region. The molecular cloud in the CMZ is much denser, warmer, and more turbulent than the disk region (¿ 1000/cc, 10-100K and 15- 50km/s in the CMZ). The molecular filaments have not been identified ubiquitously although they have been found only in G0.253+0.016 in the CMZ. Therefore, we observed the Galactic center 50km/s molecular cloud (50MC) with ALMA. In the channel maps in the CS(J=2-1) emission line, the 50MC was resolved into fine structures up to the size of 0.1pc. Then, they were identified as molecular filaments using the DisPerSE algorithm. This is the first attempt of "filament-finding" in the CMZ. These molecular filaments found in the 50MC strongly suggest that the molecular filaments are also ubiquitous in the molecular clouds of the CMZ. We estimated that the widths, the column densities and the line masses of the filaments in the 50MC are 0.3pc, 0.2-2x10^{23}/cm2 and 110-1600M/pc, respectively. The column density and the line mass are large enough to form dense cores along the filaments by gravitational instability. While the width of the filaments in the 50MC is larger than that in the disk region. As well known,there is a power law between the widths and the column densities in the disk region.The relation in the 50MC would be also described in the same power-law.

Eelco van Kampen (ESO)

Allison Noble (Univ of Toronto)
Ariadna Manilla Robles (ESO)
Gillian Wilson (UC Riverside)

Dust and CO in Distant (z=1.6) Cluster Galaxies

We present Cycle 3 ALMA data on actively star-forming galaxies in galaxy clusters at z=1.6. We show our detections (and non-detections) of continuum and CO line emission in spectroscopically-confirmed cluster members in three massive clusters from the SpARCS sample. This can be used to place constraints on the evolution of the gas fraction within and around overdense regions (cores of galaxy clusters) at z=1.6. This epoch is relevant, as it is the time where star formation is shifting between low- and high-density environments. As we have excellent auxiliary data (from the SpARCS collaboration), we can place these results in the broader context of galaxy evolution in dense environments.

Gregory Walth (UCSD)

Eiichi Egami (University of Arizona)
Benjamin Clement (CRAL Observatoire de Lyon)
Wiphu Rujopakarn (Kavli IPMU)
Tim Rawle (ESA STScI)
Marie Rex (University of Arizona)

High Resolution Observations of A Gravitationally Lensed Dusty, Star-Forming Galaxy at z~2.

Dusty, star-forming galaxies (DSFGs), characterized by their far-infrared (far-IR) emission, undergo the largest starbursts in the Universe, contributing to the majority of the cosmic star formation rate density at z = 1- 4. These starbursts have important implications for galaxy evolution and feedback as these galaxies build up much of their stellar mass during this time and may experience strong stellar driven winds. For the first time the Herschel Space Observatory was able observe the full far-IR dust emission for a large population of high-redshift DSFGs. However, Herschel reaches the confusion limit quickly and only the brightest galaxies at redshifts z > 2 can be detected. With gravitational lensing, we are able to surpass the Herschel confusion limit and probe intrinsically less luminous and therefore more normal star-forming galaxies. With this goal in mind, we have conducted a large Herschel survey, the Herschel Lensing Survey, of the cores of almost 600 massive galaxy clusters, where the effects of gravitational lensing are the strongest. In this presentation I will discuss how using one of the brightest sources from our sample allows us to investigate the molecular gas and dust properties of a typical DSFG with a CO outflow at z~2. In addition, with our recent high spatial resolution observations using HST and ALMA we can investigate this source pixel-by-pixel, unveiling its star forming properties.

Wei-Hao Wang (ASIAA)

Kotaro Kohno (University of Tokyo)
Bunyo Hatsukade (NAOJ)
Hideki Umehata (University of Tokyo)
Itziar Aretxaga (INAOE)
David Hughes (INAOE)

Near-IR Selected Objects in the SXDF-ALMA Deep Survey

Understanding the galaxies that give rise to the cosmic IR background is a key goal of ALMA. Various approaches have been employed to tackle this using existing ALMA data: deep contiguous imaging survey, serendipitous detections in deep ALMA pointings, and stacking analyses. Here we present stacking analyses on our ALMA deep 1.1 mm imaging in the SXDF using a galaxy sample selected from the CANDELS near-IR catalog. We successfully detect a faint galaxy population of $\langle F_{1.1\,\mathrm{mm}} \rangle \sim 0.03$ mJy, which corresponds to $L_{\mathrm{IR}} \sim 3 \times 10^{10}\ L_{\odot}$ and a star formation rate (SFR) of $\sim 5\ M_{\odot}\ \mathrm{yr}^{-1}$ at $z = 2$. Their stacked image is compact and unresolved by our ~ 0.5" resolution. We find that galaxies brighter in the near-infrared tend to be also brighter at 1.1 mm, and galaxies fainter than $m_{3.6\mu\mathrm{m}} = 23.0$ do not produce detectable 1.1 mm emission. This implies a correlation between stellar mass and SFR in distant galaxies. We also find tendencies that redder galaxies and galaxies at higher redshifts are brighter at 1.1 mm. By combining the fluxes of bright sources directly detected by ALMA and fluxes from faint sources detected in our stacking analyses, we recover a 1.1 mm surface brightness of up to 20.3 ± 1.2 Jy deg^{-2}, which is comparable to the IR background measured by *COBE*. We also find that approximately half of the cosmic star formation may be obscured by dust and missed by deep optical surveys, based on the fraction of optically faint sources in our and previous ALMA studies and the *COBE* IR background measurements. Much deeper and wider ALMA imaging is therefore needed to better constrain the obscured cosmic star formation history.

Kimberly Ward-Duong (Arizona State University)

Jennifer Patience (Arizona State University)
Joanna Bulger (Subaru Telescope NAOJ)
Gerrit van der Plas (Universidad de Chile)
Fran ois M nard (CNRS IPAG Univ Grenoble Alpes IPAG)
Christophe Pinte (CNRS IPAG UMI-FCA)

ALMA Observations of Disk Properties across the Brown Dwarf Boundary from the Taurus Boundary of Stellar/Substellar (TBOSS) Survey

We report 885um ALMA continuum flux densities for 24 low-mass members of Taurus, spanning the stellar/substellar boundary with spectral types from M4 to M7.75. All 24 targets are detected in either continuum or CO, with 20 detected in both. In continuum, 22 systems are detected at levels ranging from 1.0 mJy/beam to 55.6 mJy/beam. The two continuum non-detections are transition disks, though other transition disks in the sample are detected. Converting the ALMA continuum measurements to masses using standard scaling laws and radiative transfer modeling yields dust mass estimates ranging from 0.3MEarth to 20MEarth. The dust mass shows a declining trend with the mass of the central object when combined with results from submillimeter surveys of more massive Taurus members. The substellar disks appear as part of a continuous sequence and not a distinct population. Compared to older Upper Sco members with similar masses across the substellar limit, the Taurus disks are brighter and more massive. The disks around the early M-type stars in Taurus contain more mass in small solid particles than the average for heavy elements in the planetary systems found with Kepler on short-period orbits around M-dwarf stars. The disks differ in having their solid material distributed out to tens of AU from the host stars. Assuming a gas:dust ratio of 100:1, only a small number of the low-mass stars and brown dwarfs have a total disk mass amenable to giant planet formation, consistent with the low frequency of giant planets orbiting M-dwarfs.

Yoshimasa Watanabe (The University of Tokyo)

Yuri Nishimura (The University of Tokyo)
Nami Sakai (RIKEN)
Nanase Harada (ASIAA)
Kazuo Sorai (Hokkaido University)
Satoshi Yamamoto (The University of Tokyo)

CH3OH Enhancement in the Bar of M83 Observed with ALMA

Understanding of cloud-scale chemical compositions is important for studies on galactic-scale physical conditions and gas dynamics in external galaxies. It will also constitute a fundamental base for astrochemical studies of AGNs and starbursts. With this motivation, we have conducted a spectral line survey and an imaging observation toward the spiral arm region of M51 with IRAM 30 m telescope and CARMA, respectively. With these observations, we have revealed chemical compositions of molecular gas in the spiral arm at a scale from 1 kpc to 300 pc (Watanabe et al. 2014, 2016). In this study, we focus on effects of galaxy-scale gas dynamics on the chemical compositions of molecular gas in the barred spiral galaxy, because shocks are predicted in the bar by theoretical studies. Shock tracers such as SiO and CH_3OH are reported in the bar of IC 342 (Meier & Turner 2005, Usero et al. 2006), and the results are discussed in relation to shocks in the bar. We have recently observed the bar and spiral arm regions of M83 with ALMA (cycle-2) in the 3 mm band at a spatial resolution of $\sim$ 35 pc, and have compared chemical compositions of the two regions. As a result, we find that the fractional abundance of CH_3OH is significantly higher in the bar than in the spiral arm. Moreover, the line width of CH_3OH is found to be broader in the bar than in the spiral arm. This result indicates that the CH_3OH abundance is enhanced by shock in the bar. On the other hand, SiO has not been detected in this observation both in the bar and the spiral arm. The fractional abundance of SiO is found to be lower in the bar of M83 than in IC 342 by an order of magnitude, implying variation of shock strength in the bar.

Linda Watson (European Southern Observatory Chile)

The Resolved Vertical Structure of Molecular Gas in Edge-on Disk Galaxies

There is a transition in the appearance of dust in optical images of edge-on, bulgeless disk galaxies at a circular velocity of 120 km/s (stellar mass 10^{10} Msun). This transition is most likely due to a transition in the dust scale height, but could also be explained by a transition in the dust-to-gas ratio or in the properties of the stellar disk. I will present CO(2-1) data from the Submillimeter Array that spatially resolve the vertical distribution of molecular gas in two high-mass, edge-on galaxies. I will compare our direct measurements of the scale height of the cold interstellar medium to predictions from radiative transfer models, which simultaneously fit the optical appearance of the galaxy and the dust spectral energy distribution. Finally, I will describe how ALMA dust continuum and CO emission-line data for edge-on galaxies would allow us to fully test the hypothesis that there is a dust scale height transition at 120 km/s.

I hope to also present my work at the ALMA postdoc symposium after the main meeting.

Tony Wong (U Illinois)

Annie Hughes (CESR Toulouse)
Toshikazu Onishi (Osaka Prefecture U)
Akiko Kawamura (NAOJ)
Jorge L Pineda (JPL)
Juergen Ott (NRAO)

Molecular Cloud Structure in the LMC

We discuss recent high-resolution (¡1 pc) observations of giant molecular clouds in the nearest star-forming galaxy, the Large Magellanic Cloud. ALMA Band 6 observations trace the bulk of the molecular gas in CO and high column density regions in 13CO. We focus on observations of a quiescent cloud in the southern outskirts of the galaxy where star-formation activity is very low and only present at one location. We compare the cloud structure and turbulence in active and inactive regions and discuss our results in the context of dynamical models of molecular cloud evolution.

Sarah Wood (NRAO)

Mark Lacy (NRAO)
Steve Croft (UCB Wisconsin)
Rebecca Brnich (College of Charleston)
Chris Fragile (College of Charleston)

ALMA Observes Jet-Cloud Interactions In Minkowski's Object

Minkowski's Object is a dwarf galaxy that is being impacted by a jet from a nearby FRI radio galaxy. It has been identified as one of the few nearby objects where jet triggered star formation may be taking place. In this poster, we present ALMA observations detect both the CO emission from Minkowskiś Object and 110GHz continuum emission from the jet, and reprocessed VLA data in continuum and HI. Our observations are consistent with models for jet-induced star formation. We see a spatial anticorrelation of the continuum and CO emission, as expected if the dense CO clouds are being surrounded by jet plasma. We also see that the star formation efficiency is a function of distance along the jet, with more efficient star formation on the upstream side of the interaction. We are using our observations to inform models for jet induced star formation (see related poster by Brnich et al.), which may be an important aspect of AGN feedback in high redshift galaxies.

Sarah Wood (NRAO)

Erica Keller (NRAO)
Catarina Ubach (NRAO)
Paul Fisher (NRAO)
Rachel Harrison (NRAO)
Dongchan Kim (NRAO)

Know Your North American Helpdesk

Do you have questions about ALMA and need help finding the answers? The ALMA Helpdesk is here to help! We have an extensive Knowledge base for you to explore and if you cannot find your answers, submit a ticket and a member of the skilled NAASC staff will answer. Discover how to find the Helpdesk, what you can find in the knowledge base, and how to submit a ticket. Meet the team that runs the North American Helpdesk and ensures that your questions are answered. Learn how this resource has been utilized by other fellow ALMA enthusiasts.

Al Wootten (NRAO)

D. C. Lis[1,2], H. A. Wootten[3], M. Gerin[4], L. Pagani[1], E. Roueff[5], [6,7], C. Vastel[8], and C.M. Walmsley[9,10]

Star Formation and Feedback: A Molecular Outflow–Prestellar Core Interaction in L1689N

We present ALMA Compact Array (ACA), *Herschel*[9], and Caltech Submillimeter Observatory (CSO) observations of the prestellar core in L1689N, which has been suggested to be interacting with a molecular outflow driven by the nearby solar type protostar IRAS 16293-2422. This source is characterized by some of the highest deuteration levels seen in the interstellar medium. The change in the NH_2D line velocity and width across the core provides clear evidence of an interaction with the outflow, traced by the high-velocity water and CO emission. Methanol and SO emission also trace regions of interaction, as do more compact regions of SiO J=8-7 and $H^{13}CN$ J=4-3 emission. Quiescent, cold gas, characterized by narrow line widths is seen in the NE part of the core, while broader, more disturbed line profiles are seen in the W/SW part. Strong N_2D^+ and ND_3 emission is detected with the ACA, extending S/SW from the peak of the single-dish NH_2D emission. The ACA data also reveal the presence a compact dust continuum source, with a mean size of ~1100 au, a central density of $(1-2) \times 10^7\,\mathrm{cm}^{-3}$, and a mass of 0.2–0.4 $M_\odot$. The dust emission peak is displaced ~5″ to the south with respect to the N_2D^+ and ND_3 emission. We see no clear evidence of fragmentation in this quiescent part of the core, which could lead to a second generation of star formation, although a weak dust continuum source is detected in this region in the ACA data.

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[9] *Herschel* is an ESA space observatory with science instruments provided by European-led Principal Investigator consortia and with important participation from NASA.

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Yoichi Tamura (Institute of Astronomy the University of Tokyo)
Kotaro Kohno (Institute of Astronomy the University of Tokyo)
Itziar Aretxaga (INAOE)
James S Dunlop (Institute for Astronomy University of Edinburgh)
Bunyo Hatsukade (NAOJ)

SXDF-ALMA 2 arcmin^2 Deep Survey: Characterizing of ALMA-Detected Continuum Sources and Millimeter line-Emitter Search

Characterizing of faint submillimeter sources and searching for millimeter line-emitter is essential to understand the cosmic star formation history. We present (1) a multi-wavelength analysis of five submillimeter sources ($S_{1.1\mathrm{mm}} = 0.54$–$2.02$ mJy) that were detected during our 1.1-mm-deep continuum survey in the SXDF-UDS-CANDELS field (2 arcmin^2, $1\sigma = 0.055$ mJy beam^{-1}) using ALMA and (2) a serendipitous detection of a millimeter line-emitter using the survey data.

(1): The two of the five sources correspond to a known single-dish (AzTEC) selected bright submillimeter galaxy (SMG), whereas the remaining three are faint SMGs newly uncovered by ALMA. If we exclude the two brightest sources, the contribution of the faint SMGs to the infrared extragalactic background light (IR EBL) is $\sim 4.1^{+5.4}_{-3.0}$ Jy deg^{-2}. One of the sources (SXDF-ALMA3) is extremely faint in the optical to near-infrared (NIR) region despite its infrared luminosity ($L_{\mathrm{IR}} \simeq 1 \times 10^{12} L_{\odot}$). By fitting the spectral energy distributions (SEDs) at the optical-to-NIR wavelengths of the remaining four ALMA sources, we obtained the photometric redshifts (z_{photo}) and stellar masses (M_*): $z_{\mathrm{photo}} \simeq 1.3$–$2.5$, $M_* \simeq (3.5$–$9.5) \times 10^{10}\ M_{\odot}$. We also derived their star formation rates (SFRs) and specific SFRs (sSFRs) as $\simeq 30$–$200 M_{\odot}$ yr^{-1} and $\simeq 0.8$–2 Gyr^{-1}, respectively. These values imply that they are main-sequence star-forming galaxies.

(2): We made a 3-dimensional data cube with a 60 MHz resolution and searched for millimeter line-emitters using `CLUMPFIND`. We find a line-emitter (SXDF-emitter1) at $\nu_{\mathrm{obs}} = 237.29$ GHz with 5.4σ ($S_{\mathrm{peak}} = 3.8 \pm 0.7$ mJy). We identify an optical/NIR counterpart candidate near the emitter and its photometric redshift is $z_{\mathrm{photo}} = 0.97^{+0.13}_{-0.40}$. This suggests that SXDF-emitter1 is likely to be a CO(4-3) emitter at $z = 0.687$ if the counterpart candidate is associated with the emitter. The gas mass fraction of SXDF-emitter1 [$f_{\mathrm{gas}} = M_{\mathrm{gas}}/(M_{\mathrm{gas}} + M_*) = 0.97$, 0.69; Milky Way like or M82 like CO(4-3)/CO(1-0) and CO-to-H_2 conversion factor, respectively] is much higher than estimation of semi-analytic models at the same redshift ($f_{\mathrm{gas}} = 0.2$-0.4). This implies that we can find gas rich galaxies, which have been missed in previous surveys. If the optical/NIR counterpart candidate is not associated with the emitter, it would be a [CII] emitter at $z = 5.95$. Another line detection, either CO(5-4) at $z = 0.687$ or [NII] 122 μm at $z = 5.65$, is necessary to make unambiguous line identification of SXDF-emitter1.

Kijeong Yim (Korea Astronomy and Space Science Institute)

Tony Wong (University of Illinois at Urbana-Champaign)
Richard Rand (University of New Mexico)
Eric Murphy (NRAO)

Completing a Reference Sample of Vertically Resolved Edge-on Galaxies

We study vertical structure of a sample of edge-on galaxies (NGC 891, 4013, 4157, 4565, and 5907) using BIMA/CARMA 12CO (J=1-0), VLA/EVLA HI, and Spitzer 3.6 micron data. In addition to the sample of galaxies, we plan to observe two more galaxies (NGC 1448 and IC 5052) in the southern sky using ALMA (12CO). Measurements of the gas thickness, along with radial surface density profiles of gas and stars allow us to derive (1) the average volume density of the gas and (2) the vertical velocity dispersion by solving the Poisson equation. The gas volume density provides a new approach to probing the star formation law, one that is more physically relevant to the star formation rate. The gas velocity dispersion profile is used to test the role of hydrostatic pressure in controlling the molecular to atomic gas ratio. We show that the disk thicknesses increase with radius and the velocity dispersions decrease with radius, which are contrary to the assumed constant values used in many studies. In addition, we present a linear correlation between the average SFR and the average CO disk thickness.

Ilsang Yoon (NRAO)

Black Hole Mass Measurement using Molecular Gas Kinematics: What ALMA Can Do

We study the limits of spatial and velocity resolution of radio interferometry to infer the mass of supermassive black hole (SMBH) in galactic center using kinematics of circum nuclear molecular gas, by considering different galaxy surface brightness profiles, signal-to-noise ratios (S/N) of position-velocity diagram (PVD) and systematic errors due to spatial and velocity structure of the molecular gas. We argue that for fixed galaxy stellar and SMBH mass, the required spatial and velocity resolution increases and decreases respectively with decreasing Sersic index of the galaxy surface brightness profile. We validate our arguments using simulated PVDs for varying beam size and velocity channel width. Furthermore, we consider the systematic effects to the inference of SMBH mass for some cases by simulating PVDs with spatial and velocity structure of the molecular gas, which demonstrates that their impacts are not significant for PVD with good S/N unless the spatial and velocity scale associated with the systematic effects are comparable to the angular resolution and velocity channel width of the PVD from pure circular motion. Also we caution that a bias in galaxy surface brightness profile owing to the poor resolution of galaxy photometric image can largely bias SMBH mass by an order of magnitude. This study shows the promise and the limit of ALMA observation to measure SMBH mass using molecular gas kinematics and provides a useful technical justification for ALMA proposal with science goal of measuring SMBH mass.

Hans Zinnecker (SOFIA Science Center NASA-Ames DSI)

Goran Sandell (SOFIA Science Center NASA-Ames USRA)

ALMA-SOFIA Synergies

ALMA is a high-altitude interferometric observatory which provides extreme sensitivity and high spatial resolution in the mm/submm wavelength regime. SOFIA is an airborne observatory which has broad wavelength coverage (most importantly in the 30-300 micron range), albeit with more moderate spatial resolution and sensitivity (2.5m telescope in a B747SP plane). There are many synergies between the two observatories, which will be discussed in our poster, particularly in terms of continuum observations, spectroscopy, and polarimetry. - PS. The web-link to SOFIA is http://www.sofia.usra.edu

Martin Zwaan (ESO)

Ivan Oteo (University of Edinburgh ESO)
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ALMACAL: A Wide and Deep (Sub)mm Survey Using ALMA Calibrator Observations

We are currently exploiting ALMA calibration observations to carry out a novel, wide and deep submm survey: ALMACAL. Using calibrators it is possible to carry out such a deep survey with the necessary data coming for free from science projects dedicated to a wide variety of astrophysical topics. These calibration data comprise a large number of observations in a variety of frequency bands and array configurations.

We have already processed many hundreds of calibrator observations, but the ALMACAL data base is expected to grow at a steadily increasing rate, due to higher observing efficiency and with more time devoted to science observing. In essence, ALMACAL is the most comprehensive ALMA observing project ever, in terms of observing time and the science topics it addresses.

In this presentation, we outline our survey strategy and report the first results on the detection of faint, dusty, star-forming galaxies (DSFGs). The faintest galaxies we detect would have been missed by even the deepest Herschel surveys. Our cumulative number counts have been determined independently at 870 μm and 1.2 mm from a sparse sampling of the astronomical sky, and are thus relatively free of cosmic variance. The counts are lower than reported previously by a factor of at least two.

In addition, we present ALMACAL ultra-high spatial resolution (20 mas or 150 pc) observations of dust continuum in a pair of un-lensed DSFGs at z=3.4. The spectroscopic redshifts of the two sources have been confirmed via serendipitous detection of up to nine emission lines, including H_2O, ^{12}CO(13−12) and ^{12}CO(14−13) transitions. Our ultra-high resolution data reveal that their SFR surface densities are extremely high, $\Sigma_{\rm SFR} \sim 2000$ to 5500 $M_\odot$ yr^{-1} kpc^{-2}. These values are, by far, the highest found in high-redshift galaxies and comparable to those found in the nuclei of Arp220. This highlights that long-baseline observations are essential to study and interpret the properties of dusty starbursts in the early Universe.

Finally, we discuss future ALMACAL science topics, such as intervening molecular absorption lines, blind CO emission line surveys, and quasar jets.