The first year of ALMA Science

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Violette Impellizzeri (JAO)

List of Participants

ADAMS, Mark
National Radio Astonomy Observatory
mtadams@nrao.edu

AKIYAMA, Eiji
National Astronomical Observatory of Japan
eiji.akiyama@nao.ac.jp

ALADRO, Rebeca
ESO
raladro@eso.org

ALATALO, Katherine
California Institute of Technology/IPAC
kalatalo@berkeley.edu

AMIGO, Pía
University of Valparaiso
pamigo@astro.puc.cl

ANDREANI, Paola
ESO
pandrean@eso.org

ANGELONI, Rodolfo
P. Universidad Católica de Chile
rangelon@astro.puc.cl

ARAUDO, Anabella
Universidad Nacional Autonoma de México
a.araudo@crya.unam.mx

ARAVENA, Manuel
ESO
maravena@eso.org

ARCE, Hector
Yale University
hector.arce@yale.edu

ASAKI, Yoshiharu
Institute of Space and Astronautical Science
asaki@vsop.isas.jaxa.jp

AVISON, Adam
Jodrell Bank Centre for Astrophysics,
University of Manchester
adam.avison@manchester.ac.uk

BALL, Lewis
ALMA
lball@alma.cl

BARCOS-MUÑOZ, Loreto
University of Virginia
ldb7et@virginia.edu

BARRIENTOS, Felipe
P. Universidad Católica de Chile
fbarrien@uc.cl

BARSONY, Mary
SETI Institute
mbarsony@seti.org

BOLATTO, Alberto
University of Maryland
bolatto@astro.umd.edu

BONILLA, Alexander
University of Valparaiso
alexander.bonilla@uv.cl

BRADAC, Marusa
UC Davis
marusa@physics.ucdavis.edu

BREEN, Shari
CSIRO Astronomy and Space Science
Shari.Breen@csiro.au

BRESSERT, Eli
CSIRO Astronomy and Space Science
ebressert@gmail.com

BROGAN, Crystal
National Radio Astonomy Observatory
cbrogan@nrao.edu

BRONFMAN, Leonardo
Universidad de Chile
leo@das.uchile.cl

CACERES, Claudio
University of Valparaiso
ccaceres@dfa.uv.cl

CALES, Sabrina
Universidad de Concepcion
scales@astro-udec.cl

CARILLI, Chris
National Radio Astonomy Observatory
ccarilli@nrao.edu

CASASOLA, Viviana
INAF - IRA Bolgna & Italian ARC
casasola@ira.inaf.it

CAVALIÉ, Thibault
Laboratoire d\'Astrophysique de Bordeaux
cavalie@obs.u-bordeaux1.fr

CHAPILLON, Edwige
Academia Sinica, Institute of Astronomy & Astrophysics
chapillon@asiaa.sinica.edu.tw

CHINI, Rolf
Instituto de Astronomia U.Catolica del Norte
rchini@ucn.cl

CHUNG, Eun Jung
Sejong University
ejchung@sejong.edu

CONTRERAS, Yanett
CSIRO Astronomy and Space Science
yanett@gmail.com

CORDER, Stuartt
ALMA
scorder@alma.cl

CORTES, Paulo
ALMA
pcortes@alma.cl

COSTAGLIOLA, Francesco
Chalmers University of Technology
francesco.costagliola@chalmers.se

DE OLIVEIRA ALVES, Felipe
Argelander-Institut für Astronomie
falves@astro.uni-bonn.de

DeGRAAUW, Thijs
ALMA
tdegraau@alma.cl

DeGREGORIO-MONSALVO, Itziar
ALMA
idegrego@alma.cl

DIENER, Catrina
Institute for Astronomy
cdiener@phys.ethz.ch

DOUGADOS, Catherine
Universidad de Chile
catherine.dougados@obs.ujf-grenoble.fr

DUNHAM, Michael
Yale University
michael.dunham@yale.edu

ERTEL, Steve
IPAG UJF Grenoble
steve.ertel@obs.ujf-grenoble.fr

ESPADA, Daniel
National Astronomical Observatory of Japan
daniel.espada@nao.ac.jp

EVANS, Neal
University of Texas at Austin
nje@astro.as.utexas.edu

FANG, Taotao
Xiamen University
fangt@xmu.edu.cn

FARIHI, Jay
University of Cambridge
jfarihi@ast.cam.ac.uk

FERKINHOFF, Carl
Cornell University
carl.ferkinhoff@cornell.edu

FOËX, Gaël
University of Valparaiso
foex.gael@gmail.com

FUKAGAWA, Misato
Osaka University
misato@iral.ess.sci.osaka-u.ac.jp

FULLER, Gary
University of Manchester
G.Fuller@manchester.ac.uk

GALAZ, Gaspar
P. Universidad Católica de Chile
ggalaz@astro.puc.cl

GALLEGO, Sofia
P. Universidad Católica de Chile
scgalleg@uc.cl

GALLERANI, Simona
Scuola Normale Superiore di Pisa
simona.gallerani@gmail.com

GARAY, Guido
Universidad de Chile
guido@das.uchile.cl

GARCIA-APPADOO, Diego
ALMA
dgarcia@alma.cl

GODDI, Ciriaco
ESO/JIVE
cgoddi@eso.org

HAISCH, Karl
Utah Valley University
Karl.Haisch@uvu.edu

HALES, Antonio
ALMA
ahales@alma.cl

HARDY, Eduardo
Associate Universities Inc
ehardy@nrao.cl

HERNANDEZ, Ramiro Franco
University of Bonn
rfranco@astro.uni-bonn.de

HERRERA-CAMUS, Rodrigo
University of Maryland
rhc@astro.umd.edu

HESSER, Jim
National Science Infrastructure
jim.hesser@nrc-cnrc.gc.ca

HIBBARD, John
National Radio Astonomy Observatory
jhibbard@nrao.edu

HIGUCHI, Aya
ALMA
ahiguchi@alma.cl

HIRAMATSU, Masaaki
National Astronomical Observatory of Japan
hiramatsu.masaaki@nao.ac.jp

HIRANO, Naomi
Academia Sinica, Institute of Astronomy & Astrophysics
hirano@asiaa.sinica.edu.tw

HIROTA, Tomoya
National Astronomical Observatory of Japan
tomoya.hirota@nao.ac.jp

HOGERHEIJDE, Michiel
Leiden Observatory
michiel@strw.leidenuniv.nl

HUELAMO, Nuria
CAB
nhuelamo@cab.inta-csic.es

HUNTER, Todd
National Radio Astonomy Observatory
thunter@nrao.edu

IBAR, Edo
P. Universidad Católica de Chile
edoibar@gmail.com

IMPELLIZZERI, Violette
ALMA/NRAO
vimpelli@alma.cl

INDEBETOUW, Remy
National Radio Astonomy Observatory
rindebet@nrao.edu

IONO, Daisuke
National Astronomical Observatory of Japan
d.iono@nao.ac.jp

ISHII, Shun
University of Tsukuba
ishii.shun.fw@u.tsukuba.ac.jp

IVISON, Rob
Royal Observatory Edinburgh
rji@roe.ac.uk

JEWELL, Phil
National Radio Astonomy Observatory
pjewell@nrao.edu

JOHNSON, Kelsey
University of Virginia
kej7a@virginia.edu

JOHNSTONE, Doug
NRC Canada
doug.johntone@nrc-cnrc.gc.ca

JORGENSEN, Jes
University of Copenhagen
jeskj@nbi.dk

KAMENETZKY, Julia
University of Colorado
julia.kamenetzky@colorado.edu

KAWABE, Ryohei
ALMA
rkawabe@alma.cl

KEATING, Marylin
ALMA
mkeating@alma.cl

KIM, Sam
P. Universidad Católica de Chile
skim@astro.puc.cl

KIM, Sungeun
Sejong University
sek@sejong.ac.kr

KIYOKANE, Kazuhiro
The University of TOKYO, JAPAN
kazuhiro.kiyokane@nao.ac.jp

KOCH, Patrick
Academia Sinica, Institute of Astronomy & Astrophysics
pmkoch@asiaa.sinica.edu.tw

KOHNO, Kotaro
University of Tokyo
kkohno@ioa.s.u-tokyo.ac.jp

KOMUGI, Shinya
ALMA
skomugi@alma.cl

KURONO, Yasutaka
National Astronomical Observatory of Japan
yasutaka.kurono@nao.ac.jp

LACKINGTON, Matias
University of Manchester
matias@jb.man.ac.uk

LAI, Shih-Ping
National Tsing Hua University, Taiwan
slai@phys.nthu.edu.tw

LAING, Robert
ESO
rlaing@eso.org

LEON, Stéphane
ALMA
sleon@alma.cl

LOISEAU, Nora
XMM-Newton, ESAC
Nora.Loiseau@sciops.esa.int

LONSDALE, Carol
National Radio Astonomy Observatory
clonsdal@nrao.edu

LU, Jufu
Xiamen University
fangt@xmu.edu.cn

LÜDKE, Everton
Universidade Federal de Santa Maria
eludke@hotmail.com

LUNDGREN, Andreas
ALMA
alundgre@alma.cl

MAERCKER, Matthias
ESO/Alfa
mmaercke@eso.org

MAGALHAES, Antonio
IAG - Univ. Sao Paulo
mario@astro.iag.usp.br

MARCAIDE, Jon
Universidad de Valencia
j.m.marcaide@uv.es

MARCELINO, Nuria
National Radio Astonomy Observatory
nmarceli@nrao.edu

MARDONES, Diego
Universidad de Chile
diego@das.uchile.cl

MARTIN, Sergio
ESO
smartin@eso.org

MATHYS, Gautier
ALMA
gmathys@eso.org

MATSUZAWA, Ayumu
Graduate University of Adbanced Studies/NAOJ
ayumu.matsuzawa@nao.ac.jp

McCOY, Mark
New Mexico Tech
mmccoy@nmt.edu

MELNICK, Jorge
ESO
jmelnick@eso.org

MERELLO, Manuel
University of Texas at Austin
manuel@astro.as.utexas.edu

MESSIAS, Hugo
Universidad de Concepcion
hmessias@astro-udec.cl

MIGNANO, Arturo
IRA - INAF
amignano@ira.inaf.it

MOLLÁ, Mercedes
CIEMAT
mercedes.molla@ciemat.es

MOMOSE, Munetake
Ibaraki University
momose@mx.ibaraki.ac.jp

MOÓR, Attila
Konkoly Observatory
moor@konkoly.hu

MORENO, Raphael
Observatoire de Paris
raphael.moreno@obspm.fr

MULLER, Sebastien
Onsala Space Observatory
mullers@chalmers.se

MUÑOZ, Alejandra
P. Universidad Católica de Chile
amma.19@gmail.com

MURILLO, Nadia
National Tsing Hua University
nmurillo@gmail.com

MURPHY, David
P. Universidad Católica de Chile
dmurphy@astro.puc.cl

MUTO, Takayuki
Kogakuin University
muto@cc.kogakuin.ac.jp

MUXLOW, Tom
UK ALMA Regional Centre
twbm@jb.man.ac.uk

NAGAI, Hiroshi
National Astronomical Observatory of Japan
hiroshi.nagai@nao.ac.jp

NAGAO, Tohru
Kyoto University
tohru@kusastro.kyoto-u.ac.jp

NAGAR, Neil
Universidad de Concepcion
nagar@astro-udec.cl

NAKOS, Theodoros
ALMA
tnakos@alma.cl

NYMAN, Lars-Ake
ALMA
lnyman@alma.cl

OHASHI, Nagayoshi
National Astronomical Observatory of Japan
nohashi@naoj.org

ONISHI, Kyoko
The Graduate University for Advanced Studies
kyoko.onishi@nao.ac.jp

ONISHI, Toshikazu
Osaka Prefecture University
ohnishi@p.s.osakafu-u.ac.jp

OSTEN, Rachel
Space Telescope Science Institute
osten@stsci.edu

OTT, Juergen
National Radio Astonomy Observatory
jott@nrao.edu

PADGETT, Deborah
NASA/Goddard Space Flight Center
deborah.l.padgett@nasa.gov

PALADINO, Rosita
IRA - Italian ALMA regional center
paladino@ira.inaf.it

PECK, Alison
National Radio Astonomy Observatory
apeck@nrao.edu

PERETTO, Nicolas
CEA Saclay
nicolas.peretto@cea.fr

PEREZ, Laura
National Radio Astonomy Observatory
lperez@nrao.edu

PEREZ, Sebastian
Universidad de Chile
ebanube@gmail.com

PHILLIPS, Neil
ALMA
nphillip@alma.cl

PINEDA, Jaime
ESO and University of Manchester
jaime.pineda@manchester.ac.uk

PLUNKETT, Adele
Yale University, Universidad de Chile
adele.plunkett@yale.edu

RATHBORNE, Jill
CSIRO Astronomy and Space Science
Jill.Rathborne@csiro.au

RAWLINGS, Mark
National Radio Astonomy Observatory
mrawling@nrao.edu

RIBEIRO, Nadili
IAG - USP
nadili.ribeiro@usp.br

RICCI, Luca
California Institute of Technology
lricci@astro.caltech.edu

RICHARDS, Anita
UK ARC Node, University of Manchester
amsr@jb.man.ac.uk

RODON, Javier
ESO
jrodon@eso.org

RUSHTON, Anthony
ESO
anthony.rushton@eso.org

RUSSELL, Helen
University of Waterloo
helen.russell@uwaterloo.ca

SAHAI, Raghvendra
NASA
sahai@jpl.nasa.gov

SAIGO, Kazuya
National Astronomical Observatory of Japan
saigo.kazuya@nao.ac.jp

SAJINA, Anna
Tufts University
Anna.Sajina@tufts.edu

SAKAMOTO, Kazushi
ASIAA
ksakamoto@asiaa.sinica.edu.tw

SALGADO, Francisco
Leiden Observatory
salgado@strw.leidenuniv.nl

SALTER, Demerese
P. Universidad Católica de Chile
dsalter@astro.puc.cl

SALYK, Colette
National Optical Astronomy Observatory
csalyk@noao.edu

SCOTT, Kimberly
National Radio Astonomy Observatory
kscott@nrao.edu

SERVAJEAN, Elise
Universidad de Chile
eservaje@das.uchile.cl

SHEEN, Yun-Kyeong
Universidad de Concepcion
yksheen@astro-udec.cl

SHETH, Kartik
National Radio Astonomy Observatory
ksheth@nrao.edu

SILVA BUSTAMANTE, Andrea
Trufts University
andrea.silva@tufts.edu

SIRINGO, Giorgio
ALMA
gsiringo@alma.cl

SOLIS, Basilio
Planetarium of University of Santiago
bsolis1984@gmail.com

STACEY, Gordon
Cornell University
gjs12@cornell.edu

STAPELFELDT, Karl
NASA/Goddard Space Flight Center
Karl.r.stapelfeldt@nasa.gov

STEFL, Stanislav
ALMA
sstefl@alma.cl

TACCONI, Linda
MPE Garching
linda@mpe.mpg.de

TACHIHARA, Kengo
ALMA
ktachiha@alma.cl

TAN, Jonathan
University of Florida
jt@astro.ufl.edu

TANG, Ya-Wen
IInstitute of Astronomy and Astrophysics,
Academia Sinica, Taiwan
ywtang@asiaa.sinica.edu.tw

TARENGHI, Massimo
ESO
mtarengh@eso.org

TATEMATSU, Ken'ichi
National Astronomical Observatory of Japan
k.tatematsu@nao.ac.jp

TESTI, Leonardo
ESO
ltesti@eso.org

TREISTER, Ezequiel
Universidad de Concepcion
etreiste@astro-udec.cl

UEDA, Junko
University of Tokyo/NAOJ
junko.ueda@nao.ac.jp

van der MAREL, Nienke
Leiden Observatory
nmarel@strw.leidenuniv.nl

Van der Plas, Gerrit
Universidad de Chile
gerritvanderplas@gmail.com

Van DISHOECK, Ewine
Leiden Observatory / MPE
ewine@strw.leidenuniv.nl

VanKEMPEN, Tim
Leiden Observatory / Joint ALMA Offices
kempen@strw.leidenuniv.nl

VIEIRA, Joaquin
California Institute of Technology
vieira@caltech.edu

VILA, Baltasar
ALMA
bvilavil@alma.cl

VILLARD, Eric
ALMA
evillard@alma.cl

VLAHAKIS, Catherine
ALMA
cvlahaki@alma.cl

VORONKOV, Maxim
CSIRO Astronomy and Space Science
Maxim.Voronkov@csiro.au

WAELKENS, Christoffel
Institute for Astronomy KULeuven
christoffel@ster.kuleuven.be

WAGG, Jeff
ESO/Cavendish Labs
jwagg@eso.org

WILSON, Christine
McMaster University
wilson@physics.mcmaster.ca

WOOTTEN, Al
National Radio Astonomy Observatory
awootten@nrao.edu

XU, Kevin
California Institute of Technology
cxu@ipac.caltech.edu

YAN, Lin
California Institute of Technology
lyan@ipac.caltech.edu

YUSUKE, Miyamoto
University of Tsukuba
miyamoto.yusuke.gm@u.tsukuba.ac.jp

ZAPATA, Luis
CRyA-UNAM
lzapata@crya.unam.mx

ZINNECKER, Hans
Deutsches SOFIA Institut, NASA Ames Res. Center
hzinnecker@sofia.usra.edu

Part one

Oral Presentations*

* Abstracts of oral contributions appear in chronological order of their presentation

ALMA Science: Dreams to Reality

Stuartt A. Corder[1]
[1] *Joint ALMA Observatory, 3107 Alonso de Cordova, Vitacura, Santiago, Chile*

For millimeter and sub millimeter astronomy, the Atacama Large Millimeter/submillimeter Array represents a dramatic advance. Observations that were time consuming or impossible are often achieved with relative ease, ushering in a new era of high-resolution submillimeter astronomy. Taking ALMA from concept to early science required decades of intense effort by countless numbers of scientists around the globe. Here I highlight successes and trials faced in the last steps in the process, the integration and commissioning of ALMA as the world's foremost millimeter/submillimeter telescope.

Galaxy Evolution with ALMA

Linda Tacconi[1]
[1] *MPE, Garching, Germany*

Our understanding of the formation and evolution of galaxies has improved dramatically over the past decade. We now have a robust outline of the global evolution of galaxies since as early as 1-2 billion years after the Big Bang right up to the present epoch. However, we have yet to understand how exactly galaxies assembled their mass and evolved with time. The major limitation is our incomplete knowledge of the relevant mechanisms that control the phase, angular momentum, cooling, and dynamics of the baryonic matter. ALMA will be a crucial facility for addressing many of the biggest outstanding issues in galaxy evolution. I will discuss potential areas where progress will be most dramatic through ALMA data, such as kinematics, star formation and cold gas properties of star forming galaxies. I will show, where appropriate, results from ALMA early science and from the PdBI, and put these into the context of the full ALMA capabilities.

Reformation of Cold Molecular Gas Disks in Merger Remnants

J. Ueda[1,2,3], D. Iono[2], M. Yun[4], D. Wilner[3], D. Narayanan[5], B. Hatsukade[6], Y. Tamura[1], H. Kaneko,[7], A. Crocker[4], D. Espada[2], R. Kawabe[2,8]
[1] *University of Tokyo, Japan* [2] *National Astronomical Observatory of Japan, Japan* [3] *Harvard-Smithsonian Center for Astrophysics, USA* [4] *University of Massachusetts, USA* [5] *University of Arizona, USA* [6] *Kyoto University, Japan* [7] *University of Tsukuba, Japan* [8] *Joint ALMA Office, Chie*

Major merger of two disk galaxies are widely believed to provide a way to form a spheroid-dominated early-type galaxy. Contrary to this classical scenario, recent simulations with more realistic gas physics have shown that some major mergers will reform extended molecular gas disks after merging and then reemerge disk dominated late-type galaxies. For observational approach to this scenario, we newly observed in CO lines or analyzed CO archival data for 34 merger remnants ($L_{\rm FIR}$ = 10^{9-12} $L_{\odot}$), out of which 17 are ALMA Cycle 0 data, and the others are either from SMA, CARMA, PdBI or ALMA-SV data. The sample selection is based on K-band morphology suggesting advanced stages of the merger. The stellar component in a majority of the sample has undergone violent relaxation. We found disk-like distribution of molecular gas with velocity fields such as rigid or flat rotation for more than half of the sample, suggesting that CO disks have been formed in some of these. The sizes of the CO disks range from 1.4 kpc to 9.6 kpc, and the spatial extent of the largest CO disk is comparable to the size of the Milky Way disk.

ALMA Exploration of Warm Molecular Gas in Nearby LIRGs

C.K. Xu[1], A. Evans[2], N. Lu[1], P. van der Werf[3], P. Appleton[1], L. Armus[1], V. Charmandaris[4], T. Diaz-Santos[1], Y. Gao[5], J. Livingston[1], S. Lord[1], J. Mazzarella[1], D. Sanders[6], B. Schulz[1], S. Stierwalt[1]
[1] *IPAC, Caltech*
[2] *NRAO*
[3] *Leiden Observatory*
[4] *University of Crete*
[5] *Purple Mountain Observatory*
[6] *IfA, University of Hawaii*

I will present ALMA observations of the CO J=6-5 line emission and the 450 micron continuum of nearby luminous infrared galaxies (LIRGs). These observations exploited the best angular resolution (0.23") that ALMA can achieve in its shortest wavelength band (Band-9) available for Cycle-0, and aimed to resolving for the first time distributions of warm molecular gas ($T > 50$K) and sub-millimeter dust radiation in LIRGs with spatial resolutions better than 100 pc. The high spatial and velocity resolutions of the observations are crucial in distinguishing different nuclear gas configurations, e.g., outflow or inclined circum-nuclear disks.

Molecular gas and AGN feedback in galaxy cluster cores

H. R. Russell[1], B. R. McNamara[1,2,3], R. A. Main[1], A. N. Vantyghem[1], F. Combes[4], A. C. Edge[5], P. Salomé[4], C. P. O'Dea[6], E. Egami[7], J. B. R. Oonk[8] et al.
[1] *University of Waterloo*
[2] *Perimeter Institute for Theoretical Physics*
[3] *Harvard-Smithsonian Center for Astrophysics*
[4] *LERMA, Observatoire de Paris*
[5] *Durham University*
[6] *Rochester Institute of Technology*
[7] *Steward Observatory, University of Arizona*
[8] *Netherlands Institute for Radio Astronomy*

The brightest cluster galaxies in the cooling clusters A1664 and A1835 both harbour more than $10^{10}\ \mathrm{M}_\odot$ of molecular gas and nuclear starbursts at levels not seen except in the early Universe. The molecular gas, which probably formed from hot gas cooling out of the clusters' X-ray atmospheres, may be fuelling the powerful AGN outbursts observed as expanding radio bubbles, shocks and gas outflows. Our ALMA Early Science observations of these relatively nearby systems show the bulk of the molecular gas is centrally condensed and spatially coincident with the star formation. In A1664, extended molecular gas filaments trace low temperature X-ray and Hα-emitting material, which could mark residual cooling from the hot atmosphere. The CO(3-2) velocity map shows a rotating molecular disk, potentially fuelling the AGN, and a spectacular $\sim 10^{10}\ \mathrm{M}_\odot$ filament projected across the nucleus at $\sim 600\ \mathrm{km\ s^{-1}}$ with respect to the systemic speed. This gas was either ejected from the nucleus by the AGN or is falling onto the system at high speed. In A1835, we also observe molecular filaments drawn up around the northern radio bubble suggesting for the first time that radio jets interact with the cold, dense molecular gas as well as the hot, diffuse intracluster medium.

Hot Potatoes: Compact Obscured Nuclei with ALMA

Costagliola F.[1], Aalto S.[1], Sakamoto K.[2], Muller S.[1]
[1] *Onsala Space Observatory (Sweden)*
[2] *Academia Sinica Institute of Astronomy and Astrophysics (Taiwan)*

Evidence is now mounting that most of the activity in some luminous infrared galaxies takes place in their compact obscured nuclei (CONs), regions of less than 100 pc in diameter, which harbor large amounts of warm (T$>$100 K) molecular material (N(H_2)$> 10^{24}$ cm^{-2}). The combined effect of warm, shielded gas and intense infrared radiation produce rich molecular spectra, which make these objects unique laboratories to study molecular excitation in extreme environments. Also, recent studies have shown that such compact nuclei may drive extremely young (1-2 Myr) molecular outflows, and are thus ideal targets to study AGN/starburst feedback processes. Here we will present some first results from Cycle 0 observations of two obscured nuclei. In the prototypical CON of NGC 4418 we proposed a 170 GHz-wide spectral scan in bands 3, 6 and 7, aimed at obtaining a template for the molecular chemistry and excitation in CONs. In NGC 1377, the galaxy with the highest far-IR/radio ratio observed to date, we successfully mapped the molecular outflow in CO 1-0 and obtained the first detection of the continuum at wavelengths $>$1 mm. What is driving the outflow, and why is NGC 1377 so radio-deficient ?

Feeding and feedback in the nearby Seyfert 2 NGC 1433

V. Casasola[1,2], F. Combes[3], S. García-Burillo[4], L. K. Hunt[5], & NUGA Team
[1] *INAF-IRA, Bologna, Italy*; [2] *Italian ARC*; [3] *Obs. de Paris, LERMA, France*; [4] *Obs. de Madrid, Spain*;
[5] *INAF-OAA, Firenze, Italy*

Up to now, our NUGA study of molecular gas in AGN circumnuclear regions with IRAM has shown that embedded, kinematically decoupled bars are able to feed the nuclei; but gas inflow, assumed ubiquitous in simulations, is seen only in $1/3^{rd}$ of cases. However, we have been hampered by insufficient spatial resolution and sensitivity to trace the gas inside a 100 pc radius. ALMA ES Cycle 0 has already offered the opportunity, for the first time, to examine the ultimate contenders of nuclear gas fueling (nuclear bars, dynamical friction, and/or turbulent viscosity) improving spatial resolution by a factor 5 and sensitivity by a factor 2 with respect to our previous results on NUGA.
We present the Cycle 0 cold dense gas, ^{12}CO(3–2), map in the nearby, barred, spiral, Seyfert 2, NGC 1433 galaxy nucleus at the unprecedented spatial resolution of 20 pc. These data are fundamental to test and refine the scenario of feeding and feedback of AGN, and constrain BH models. This progress, possible only with ALMA, is also an essential step to prepare even higher resolution observations to tackle the molecular torus below 10 pc in the immediate future, when ALMA will operate in full array mode.

Mapping Shock Chemistry in NGC 1266: Local Example of AGN-driven Feedback

Katherina Alatalo.[1,2], Timothy A. Davis[3], David Meier[4], Lisa M. Young[4], Sergio Martín[5], Kristina E. Nyland[4], Alison F. Crocker[6], Philip Appleton[2]
[1] *UC - Berkeley, Berkeley, CA, USA*
[2] *IPAC / Caltech, Pasadena, CA, USA*
[3] *European Southern Observatory, Garching bei Muenchen, Germany*
[4] *New Mexico Tech, Socorro, NM, USA*
[5] *European Southern Observatory, Santiago, Chile*
[6] *University of Toledo, Toledo, OH, USA*

NGC 1266 is an S0 galaxy, observed as part of the ATLAS^{3D} effort, which remarkably hosts 10^9 $M_\odot$ of molecular gas and a large molecular outflow. The NGC 1266 CO line profile exhibits extended wings of up to ± 400 km s^{-1}, and an estimated outflow mass rate of ~ 50 $M_\odot$ yr^{-1}. High resolution CARMA observations have revealed that the bulk of the gas is concentrated within 100 pc of the nucleus. The presence of an AGN combined with molecular gas outflowing faster than v_{esc} hints that this galaxy is a local candidate for AGN feedback. The fact that the star formation rate is unable to support such a high energy outflow strengthens this claim. How the gas fell so deeply into the potential well, and the exact nature of the driving mechanism behind the expulsion of the gas remain mysterious.
Recent ALMA observations of five transitions of SiO within NGC 1266 (Alatalo et al. in prep) have shown that the molecular shocks reside within the central 100 pc, very close to the AGN, rather than in the vicinity of the ionized gas shock tracers. From these recently completed ALMA observations, we will be able to study in detail the excitation of the AGN-shock interface at the jet launchpoint of NGC 1266, shedding light on how a low luminosity AGN is able to produce a mass-loaded outflow and quench star formation in a transitioning system. Combining ALMA observations with those of Herschel provide a compelling synergy when studying systems like NGC 1266, and recent $Herschel$ [C II], [O I] and CO observations of shocked H_2 rich systems show that they are a likely analog to NGC 1266-like outflows.

A survey of strong absorption lines at z=0.89 toward PKS1830-211

Muller, Sebastien[1] et al.
[1] *Onsala Space Observatory*

The z=0.89 molecular absorber toward the lensed quasar PKS1830-211 offers the unique possibility to investigate the physico-chemical properties of the molecular gas in the disk of a galaxy with an age of less than half the age of the Universe. In ALMA cycle 0, we have targeted the strong absorption lines of most common interstellar molecules, in order to determine the structure and composition of the gas along the different lines of sight toward the lensed images of the background quasar.
In this talk, we will present the new results coming out of the ALMA observations, update the molecular inventory toward PKS1830-211 with the detection of new species, and test fundamental physics by placing constraints on the constancy of fundamental constants at z=0.89.

High mass star formation throughout the galaxy and beyond

Guido Garay[1]
[1] *Universidad de Chile*

In this contribution I will review the current status of our knowledge about the formation process of high-mass stars, drawn mainly from moderate (~ 10") angular resolution observations, and discuss the key questions that will be addressed with ALMA. A summary of the recent results derived from ALMA Early Science observations will be presented.

ALMA's view of the initial conditions within a massive protocluster

Jill Rathborne[1], Steve Longmore, [2], James Jackson[3], Jonathan Foster[4], Joao Alves[5], Leonardo Testi[6], John Bally[7], Nate Bastian[8], and Eli Bressert[9]

[1] *CSIRO Astronomy and Space Science, Australia*
[2] *European Southern Observatory, Germany*
[3] *Boston University, United States*
[4] *Yale University, United States*
[5] *University of Vienna, Austria*
[6] *European Southern Observatory, Germany*
[7] *University of Colorado, United States*
[8] *Excellence Cluster Universe, Garching, Germany*
[9] *European Southern Observatory, Germany*

Clusters are the building blocks of galaxies and the nurseries of most stellar systems. However, little is known about the formation of the most massive clusters. In recent surveys, one object, G0.25+0.02, stands out as extreme. Identified as a cold, dense, massive molecular clump devoid of current star-formation, it has exactly the properties expected for a clump that may form an Arches-like massive cluster. In this talk I will show and discuss the preliminary images and results from our recent ALMA cycle 0 observations of the 90 GHz continuum and line emission toward G0.25+0.02. The data are spectacular and provide, for the first time, details of the small-scale structure and conditions within this unique protocluster.

Globally collapsing molecular clouds as a formation mechanism for the most massive stars in the Galaxy

Nicolas Peretto[1], Gary Fuller[2,3], Ana Duarte-Cabral[4], Adam Avison[2,3], Patrick Hennebelle[1], Jaime E. Pineda[2,3,5], Philippe André[1], Sylvain Bontemps[4], Frédérique Motte[1], Nicola Schneider[4]

[1] *Laboratoire AIM, CEA-CNRS-Université Paris Diderot, IRFU, Service d'Astrophysique C.E. Saclay, France*
[2] *Jodrell Bank Centre for Astrophysics, School of Physics & Astronomy, University of Manchester, UK*
[3] *UK ALMA Regional Centre node*
[4] *Université de Bordeaux, LAB, UMR 5804, France*
[5] *European Southern Observatory (ESO), Germany*

Despite the tremendous impact of massive stars on the interstellar medium, no consensus has been reached on how they are formed. In particular, the question of what physical process determines their mass remains to be answered. On one hand, primordial fragmentation of globally stable molecular clouds may form compact reservoirs of gas from which a forming star subsequently builds its mass. In an alternative scenario, molecular clouds undergo global collapse, gathering matter from large-scales to the centre of their gravitational potential well, and continuously feeding protostars lying there. Here, we report ALMA Cycle 0 observations of a network of cold, dense, parsec-long filaments intersecting at the position of one of the most massive cores ever observed in the Galaxy. These observations show this core to have sufficient mass to form an early O-type star. ALMA reveals that both the density structure and kinematics of the system are consistent with models of globally collapsing clouds in which gas flows along converging network of filaments and feeds the central massive protostars. This study demonstrates that the evolution of molecular cloud's large-scale structure plays a central role in setting the mass of the most massive stars in the Galaxy.

The Dynamics and Chemistry of Massive Starless Cores

J. C. Tan[1], S. Kong[1], M. J. Butler[1], P. Caselli[2], F. Fontani[3]
[1] *Dept. of Astronomy, University of Florida, USA*
[2] *Dept. of Physics & Astronomy, University of Leeds, UK*
[3] *Arcetri Observatory, Firenze, Italy*

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

The birth of a massive star in G331.5-0.1

Manuel Merello[1], Leonardo Bronfman[2], Guido Garay[2], Nadia Lo[2], Lars-Ake Nyman[3], Maria Cunningham[4], Neal J. Evans[1]
[1] *University of Texas at Austin*
[2] *Universidad de Chile*
[3] *Joint ALMA Observatory (JAO)*
[4] *University of New South Wales*

We present our ALMA Cycle 0 observations of a high-velocity outflow in the multiple massive star-forming region G331.5-0.1 (7.5 kpc distant), one of the most luminous regions in the Milky Way. The outflow is among the most massive and energetic discovered so far (flow mass 55 $M_{\odot}$, momentum 2.4×10^3 $M_{\odot}$ km/s and kinetic energy 1.4×10^{48} ergs). ATCA 3.6 and 6 cm continuum observations show the presence of a compact radio source at the peak position of the outflow emission, with a spectral index between these two wavelengths that suggests the presence of an ionized jet. We mapped this region with SiO(8-7), CO(3-2), HCO+(4-3), H13CO+(4-3) and CH3OH, using ALMA Band 7, during the first part of 2012. Observations reveal the presence of a compact ringlike structure at the source velocity, with inner and outer radius of 0.7″ and 2″ respectively (0.03 and 0.07 pc at the source distance), and a high velocity emission at the center. The previous 3.6 cm radio continuum source is coincident with the center of this structure. In addition, the H13CO+ spectrum features are similar to line profiles for clouds undergoing inside-out collapse. We consider possible explanations of this structure, including a massive disk around a forming O-type star with an outflow, and/or an expanding shell.

Chemistry of interstellar medium and low mass star formation

Naomi Hirano[1]
[1] *Academia Sinica, Institute of Astronomy & Astrophysics*

Chemical structure around low-mass protostars varies significantly as the central star evolves. Protpstars in the earliest evolutionary stage are buried in cold and dense material in which most of the molecules are depleted onto dust grains. protostellar evolution is characterized by depletion of molecule, especially carbon-bearing species such as CO and CS. Once protostars start driving outflows, the chemical conditions around the stars are significantly affected by means of shocks caused by the outflows. At the same time, protostars heat their surrounding gas and release the depleted molecules into the gas phase. The evaporation of icy mantle molecules from dust grains and subsequent gas phase chemistry play important roles in forming complex organic molecules.
In this talk, I will review the latest observational results of low-mass star forming regions in different evolutionary stages, including the very impressive results of ALMA cycle 0 and SV data.

The first ALMA view of the IRAS 16293-2422 proto-binary: Direct detection of infall onto source B and high-resolution kinematics of source A

Jaime E. Pineda[1,2], Anaëlle J. Maury[1], Gary A. Fuller[2], Leonardo Testi [1,3], Diego García-Appadoo[4,5], Alison B. Peck[5,6], Eric Villard[5], Stuartt A. Corder[6], Tim A. van Kempen[5,7], Jean L. Turner[8], Kengo Tachihara[5,9], William Dent[5]
[1] *European Southern Observatory (ESO), Garching, Germany*
[2] *UK ARC Node, Jodrell Bank Centre for Astrophysics, School of Physics and Astronomy, University of Manchester, Manchester, M13 9PL, UK*
[3] *INAF-Osservatorio Astrofisico di Arcetri, Largo E. Fermi 5, I-50125 Firenze, Italy*
[4] *European Southern Observatory, Alonso de Córdova 3107, Vitacura, Casilla 19001, Santiago 19, Chile*
[5] *Joint ALMA Observatory, Alonso de Córdova 3107, Vitacura, Santiago, Chile*
[6] *North American ALMA Science Center, National Radio Astronomy Observatory, 520 Edgemont Road, Charlottesville, VA 22903, USA*
[7] *Leiden Observatory, Leiden University, PO Box 9513, 2300 RA Leiden, The Netherlands*
[8] *Department of Physics and Astronomy, UCLA, Los Angeles, CA 90095, USA*
[9] *National Astronomical Observatory of Japan, Chile Observatory, 2-21-1 Osawa Mitaka Tokyo 181-8588 Japan*
IRAS 16293-2422 is one of the most studied proto-binaries, and therefore it is important to determine their physical properties to study the fragmentation process leading to binary formation. Here we present ALMA Science Verification observations with high-spectral resolution of IRAS 16293-2422 at 220.2 GHz. The wealth of molecular lines in this source and the very high spectral resolution offered by ALMA allow us to study the gas kinematics with unprecedented detail. We present the first detection of an inverse P-Cygni profile toward source B in the three brightest lines. The line profiles are fitted with a simple two-layer model to derive an infall rate of $4.5 \times 10^{-5}\, M_{\odot}\, \mathrm{yr}^{-1}$. This infall detection would rule-out the previously suggested possibility that source B is a T Tauri star. A position velocity diagram for source A shows evidence of rotation with an axis close to the line-of-sight. These results suggest that the angular momentum of both components are not parallel.

Prebiotic molecules and water on solar system scales of low-mass protostars

Jes K. Jørgensen[1,2], Cécile Favre[3], Magnus V. Persson[2,1], Johan Lindberg[2,1], Ewine F. van Dishoeck[4,5], Suzanne E. Bisschop[2,1], Tyler L. Bourke[6], Markus Schmalzl[4]
[1] *Centre for Star and Planet Formation & Niels Bohr Institute, University of Copenhagen*
[2] *Natural History Museum of Denmark, University of Copenhagen*
[3] *University of Michigan*
[4] *Leiden Observatory, Leiden University*
[5] *Max Planck Institut für extraterrestrische Physik*
[6] *Harvard Smithsonian Center for Astrophysics*

Studies of young stars in their earliest embedded stages are of prime importance for our understanding of the formation of solar-type stars and their disks. On the one hand, they make it possible to probe the star formation process right after the collapse has occurred and thereby reveal the relationship between the protostar and the environment in which it forms. On the other hand, the initial conditions for the subsequent chemical evolution of the protoplanetary disk are determined during these embedded stages. I will present some of the results from the first ALMA Science Verification and Cycle 0 observations of the chemistry of low-mass protostars on Solar System scales. In particular, these observations show the first detection of glycolaldehyde, a simple sugar-like prebiotic molecule, in the inner infalling regions around a low-mass protostar. The observations also show the presence of water vapor in the same gas: the relative abundances of different isotopologues of water reveal a deuterium fractionation similar to cometary water. These observations underline the rich and important chemistry occuring already during these early stages and demonstrate the exciting promise of ALMA for studies for the chemistry for the early stages of star and planet formation.

Deciphering VLA1623: a triple non-coeval system with a First Core candidate?

Nadia M. Murillo[1], Shih-Ping Lai[1]
[1] *National Tsing Hua University, Taiwan*

Ubiquitous at every evolutionary stage, Multiple Protostellar Systems (MPSs) are considered to be formed through core or envelope fragmentation, but the details are unclear. The coevality, multiplicity and environment of early stage MPSs provide crucial insight into their formation and evolution process. The possibility of fragmentation and collapse of a protostar's envelope makes MPSs good targets in the search for the elusive First Core. We present our multiwavelength study of VLA1623, located in ρ Ophiuchus, using SMA and ALMA Early Science Cycle 0 observations. We find VLA1623 to be a curious MPS with three non-coeval components each with different physical and chemical environments. Most surprisingly we find the Class 0 source VLA1623A to have a Keplerian disk, VLA1623W to be a Class I protostar, and VLA1623B to be an extremely cold ($T_D \sim 5$K) and extremely low luminosity ($L_{bol} \sim 10^{-5}$) object with strong CO depletion. We suspect VLA1623B is between the starless core and Class 0 stages, given its physical and chemical properties, making it a good First Core candidate. VLA1623 is a good example of how MPSs can serve as star formation laboratories.

The largest circumstellar disk - Birth of a high-mass star?

Rolf Chini[1,2], Katrien Steenbrugge[1], Dieter Nürnberger[2]
[1] *Instituto de Astronomía, Universidad Católica del Norte, Antofagasta, Chile*
[2] *Astronomisches Institut, Ruhr-Universität Bochum, Universitätsstraße 150, D-44780 Bochum, Germany*

In 2004 we discovered a 24.000 AU symmetric disk silhouette with a central stellar source and a bipolar nebula perpendicular to the triangular absorption pattern in a region of high-mass star formation within M 17. ^{13}CO (1-0) data from PdBI indicate that the object is rotating. Optical and infrared imaging shows a bipolar jet while a wealth of emission lines with shapes typical for accreting YSOs could be observed from the central object. Since then there is the debate whether this is the first case where the formation of a high-mass star via disk accretion is directly observed in analogy to the scenario for low-mass stars.
The disk is unambiguously detected in our ALMA Cycle 0 observations in the molecular lines ^{13}CO (2-1) and C^{18}O (2-1) at an angular resolution of 0.9×0.5 arcsec^2 which is a factor of ten higher compared to our earlier PdBI data. This allows us to trace the kinematics of the molecular gas in the disk and to constrain its rotation curve as well as the mass of the central YSO. The ALMA data will resolve the long-standing questions whether the disk mass is gravitationally bound to the central object and whether it is sufficiently large to create a high-mass star.

Observations of the centimeter/(sub)millimeter H_2O masers in Orion KL with ALMA and VERA

T. Hirota[1,2], M. Tsuboi[3], K. Fujisawa[4], M. Honma[1,2], H. Imai[5], M. K. Kim[1], Y. Kurono[1], T. Shimoikura[6], Y. Yonekura[7]
[1] *National Astronomical Observatory of Japan, Japan*
[2] *The Graduate University for Advanced Studies (SOKENDAI), Japan*
[3] *Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, Japan*
[4] *Faculty of Science, Yamaguchi University, Japan*
[5] *Graduate School of Science and Engineering, Kagoshima University, Japan*
[6] *Department of Astronomy and Earth Sciences, Tokyo Gakugei University, Japan*
[7] *Center for Astronomy, Ibaraki University, Japan*

We will present the results of our observational studies with VERA (VLBI Exploration of Radio Astrometry) and ALMA of an outburst of the 22 GHz H_2O masers in Orion KL detected since early 2011. We have found that the bursting masers are located at the molecular peak of the Orion Compact Ridge suggesting a shock excitation as the possible origin. Our high-resolution 1.3 mm dust continuum observations with ALMA cycle 0 in its extended configuration reveals that a compact dust continuum peak is coincident with the position of the bursting maser features. Further details will be discussed based on the forthcoming data.
In addition, we will also report the first detection of the 232 GHz vibrationally excited H_2O maser in Orion KL based on the ALMA Science Verification data. The 232 GHz maser is detected only at the position of the radio Source I, and its spectral profile shows a double-peaked structure analogous to the 22 GHz H_2O maser and the 43 GHz SiO maser associated with Source I. Our result suggests that the 232 GHz H_2O maser would be excited by the internal heating by an embedded protostar, being associated with either the root of the outflows/jets or the circumstellar disk around Source I.

Structure and Effects of Environment in the Outflow from Massive YSO Orion Source I revealed by ALMA

Goddi Ciriaco[1], Niederhofer Florian[2], Humphreys Elizabeth[2]
[1] *Joint Institute for VLBI in Europe, Postbus 2, 7990 AA, Dwingeloo, The Netherlands*
[2] *European Southern Observatory, Karl-Schwarzschild-Strasse 2, D-85748 Garching, Germany*

The details of how massive stars form are poorly known. Radio Source I at the center of the Orion BN/KL nebula provides the nearest example of a high-mass young stellar object (YSO), and hence offers unique chances for a detailed study of accretion and outflow processes in massive YSOs. Detailed imaging of molecular gas at protostellar radii of 10-1000 AU has revealed a beautiful example of disk-mediated accretion and (magnetic) outflow recollimation in a high-mass YSO. On larger scales, however, the morphology and velocity field of the outflow appear rather complex, and not readily interpretable in the framework of a rotating flow collimated by magnetic processes. In particular, we imaged with ALMA several SiO (J=5-4) transitions from different isotopologues, probing the outflow on scales of 500-5000 AU from Source I. I will discuss the new structures revealed by ALMA in the context of the simultaneous presence of several complex phenomena in the BN/KL region: a dense protostellar cluster, dense gas in the Hot-Core, the explosive bullet outflow, and the recent history of a dramatic stellar interaction. The unprecedented imaging capabilities of ALMA, together with the close distance of Orion BN/KL, have enabled unveling of the effects of the complex environment of a massive star forming region on a single protostellar outflow.

Outflow Entrainment in HH46/47

Diego Mardones[1], Hector Arce[2], Stuart Corder[3], Guido Garay[1], Alberto Noriega-Crespo[4], Alex Raga[5], & Sylvie Cabrit[6]
[1] *Universidad de Chile* [2] *Yale University* [3] *ALMA Observatory* [4] *IPAC* [5] *UNAM* [6] *Observatoire de Paris*

We present an ALMA cycle-0 29-beam mosaic of CO 1–0 emission towards the HH 46/47 outflow with 3.5” resolution. HH 46/47 is a nearby Bok globule hosting an early Class I protostar with one of the best defined outflow cavities in the IR. It also hosts an optical jet coming out of the cloud with an IR counter-jet going in. Thus, HH 46/47 is one of the best candidates to probe the wind/cloud interaction at high resolution. We achieve spatial, outflow speed, and mass sensitivity dynamic ranges of approximately a factor of 30 each. We recover 100% of the SEST 50” beam flux at speeds above 1.3 km/s from the core rest speed, indicating a surprising lack of extended flux at high velocities requiring ACA observations. We clearly detect: (a) a red jet-like structure extending from the protostar to the south-western end of the core; (b) multiple morphological and kinematic cavities, with a periodicity in the range of 300-1200 yrs; (c) and a wide-angle wind component towards both red and blue outflow lobes. The data are consistent with a jet-driven + wide angle outflow model at an inclination of 36°, and a mass-velocity power law exponent of -2.6. These can be partially explained by the Lee et al (2001) hydrodynamic outflow models, likely requiring more realistic parent core structure.

Study of first light with ALMA

C. Carilli
[1] *NRAO*

Determining the nature of the first galaxies and supermassive black holes, and in particular, the galaxies that 'reionize' the neutral IGM after recombination, is one of the primary science goals in modern astronomy. The orders-of-magnitude improvement in sensitivity afforded by ALMA opens a new window on very early galaxy evolution, through the study of the cool gas and dust. Such studies complement optical studies of stars and star formation. A critical capability of ALMA is observation of the atomic fine structure line emission, and in particular the strong [CII] 158um line. These lines redshift into the (sub)mm windows at z > 4. A major difficulty in the study of the first galaxies, into cosmic reionization, is obtaining spectroscopic redshifts: the standard rest-frame UV lines redshift into the near- and mid-IR, while Gunn-Peterson scattering by the neutral IGM greatly attenuates the Lya emission. ALMA has the sensitivity to detect relatively low star formation rate galaxies (a few Msun/year) in [CII] emission well into reionization (z > 7, although the lack of Band 5 represents a redshift hole from z= 8 to 10). The [CII] line will likely become a standard 'spectroscopic redshift machine' for the first galaxies, which may be problematic otherwise. The strength of the [CII] line also allows for high resolution spectroscopic imaging of the gas dynamics in the first galaxies. I will present the first (sub)mm studies of the cool gas and dust in the most distant galaxies, including quasar host galaxies, SMGs, and possibly more normal star forming galaxies.

High redshift starburst galaxies revealed by SPT, ALMA, and gravitational lensing

J. D. Vieira[1] and SPT collaboration
[1] *Caltech*

The South Pole Telescope (SPT) has systematically identified a large number of high-redshift strongly gravitationally lensed starburst galaxies in a 2500 deg^2 cosmological survey of the millimeter (mm) sky. These sources are selected by their extreme mm flux, which is largely independent of redshift and lensing configuration. The flux magnification provided by the gravitational lensing enabled us to perform a spectroscopic redshift survey with the recently commissioned Atacama Large Millimeter Array (ALMA). We targeted 26 SPT sources and obtained redshifts via molecular carbon monoxide (CO) lines. We determine that roughly 40% of these sources lie at $z > 4$, indicating the fraction of dusty starburst galaxies at high-redshift is far higher than previously thought. Two sources are at $z = 5.7$, placing them among the highest redshift starbursts known, and demonstrating that large reservoirs of molecular gas and dust can be present in massive galaxies near the end of the epoch of cosmic reionization. These sources were additionally targeted with high resolution imaging with ALMA, unambiguously demon strating them to be strongly gravitationally lensed by foreground structure. We are undertaking a comprehensive and systematic followup campaign to use these "cosmic magnifying glasses" to study the infrared background in unprecedented detail, inform the condition of the interstellar medium in starburst galaxies at high redshift, and place limits on dark matter substructure. I will discuss the scientific context and potential for these strongly lensed starburst galaxies, give an overview of our team's extensive followup efforts, and describe our latest science results.

Herschel-ATLAS and ALMA. I. An Einstein Ring of Molecular Gas and Dust in the z=1 source G15.v2.19

Hugo Messias[1], Gustavo Orellana[1], Neil Nagar[1], Shane Bussmann[2], Jae Calanog[3], Asantha Cooray[3], Simon Dye[4], Hai Fu[3], Edo Ibar[5], Rob Ivison[6,7], Mattia Negrello[8], Dominik A. Riechers[9], Yun-Kyeong Sheen[1], Ricardo Demarco[1]

[1] *Departamento de Astronomía, Universidad de Concepción, Barrio Universitario, Concepción, Chile*
[2] *Steward Observatory, Department of Astronomy, University of Arizona, Tucson, USA*
[3] *Department of Physics & Astronomy, University of California, Irvine, USA*
[4] *Cardiff University, School of Physics & Astronomy, Cardiff, UK*
[5] *Pontificia Universidad Católica de Chile, Santiago, Chile*
[6] *UK Astronomy Technology Centre, Science and Technology Facilities Council, Royal Observatory, Edinburgh, UK*
[7] *Institute for Astronomy, University of Edinburgh, Edinburgh, UK*
[8] *Osservatorio Astronomico di Padova, INAF, Italy*
[9] *Astronomy Department, California Institute of Technology, Pasadena, CA, USA*

Among the several contributions of the Herschel-ATLAS survey, one which stands out is the reliable selection of gravitational lens systems by means of a simple far-infrared flux cut (Negrello et al. 2010). This talk is about one of the brightest source in the sample (with $S_{500\,\mu\mathrm{m}} = 194$ mJy), which has been observed with ALMA. Two scheduling blocks (SBs) have been delivered so far. These comprise Bands 3 (with 25 antennas) and 6 (17) setups, observed in extended configuration (maximum baseline $\sim$450 m). The continuum emission (at 101 and 226 GHz) was successfully detected, as well as line emission from the following transitions: ^{12}CO J:2$\rightarrow$1 and J:4$\rightarrow$3; CI $^3\mathrm{P}_1 \rightarrow ^3\mathrm{P}_0$; and CS J:10$\rightarrow$9. Ancillary data (HST, Keck-AO) shows a typical quad lensed system close to a fold caustic, with a nearly complete Einstein ring. However, obscuration induced by the foreground lens disc galaxy has so far prevented an acceptable lens model. Nevertheless, the CO line has a FWHM narrower than those observed in SMGs and shows a double peaked profile. This, together with an impressive CS J:10-9 detection and its observed FIR flux, hints for a highly dense environment and a high magnification.

ALMA and JVLA Observations of Highly Obscured Infrared Luminous Jet-dominated Quasars in a Strongly AGN-Dominated Phase

Carol Lonsdale[1], Mark Lacy[1], Amy Kimball[1], Jim Condon[1], Colin Lonsdale[2], Robyn Smith[3], Andrew Blain[4], Minjin Kim[5], Dan Stern[6], Roberto Assef[6], Chao-Wei Tsai[6], Peter Eisenhardt[6], Jingwen Wu[6], Tom Jarrett[7] and Carrie Bridge[7]

[1] *National Radio Astronomy Observatory, 520 Edgemont Road, Charlottesville, VA 22903, USA*

[2] *MIT Haystack Observatory, Westford, MA 01886, USA*

[3] *Drexel University, 3141 Chestnut Street, Philadelphia, PA 19104, USA*

[4] *Physics & Astronomy, University of Leicester, 1 University Road, Leicester, LE1 7RH, UK*

[5] *The Observatories of the Carnegie Institution for Science, 813 Santa Barbara Street, Pasadena, CA 91101, USA*

[6] *Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, USA*

[7] *California Institute of Technology, Pasadena, CA 91125, USA*

I will present ALMA 345 GHz (870μm) observations for a complete sample of 49 of the most highly luminous obscured radio-moderate quasars in the universe, which are excellent candidates for studying radio jet-driven feedback processes. Identification of these rare quasars has been made possible by selecting mid-IR bright red WISE sources with compact NVSS radio sources. Our results demonstrate the outstanding power of ALMA, even with only 15−23 12m antennas and only 90s of integration time, to return game-changing science. The redshift range is 0.5−2.5, the bolometric luminosities are in the ULIRG and HLIRG range, reaching $10^{14}L_{\odot}$ for one source, and the 345 GHz sources are unresolved on $\sim$5 kpc scales. The bolometric luminosities are dominated by warm AGN-heated dust emission in most sources however star formation rates of up to several hundred solar masses per year may be present in some. Imaging at 8 and 11 GHz with the JVLA reveals cores unresolved on $\sim$1 kpc scales and radio powers in the FRI/II transition range, log L_{20cm} = 25-27.5 W/Hz. Future imaging in CO with ALMA & JVLA, and in the radio continuum with the VLBA, will investigate the interaction of the young jets with the molecular medium.

ALMA reveals a chemically evolved submillimeter galaxy at z=4.76

Tohru Nagao[1,2], R. Maiolino[3], C. De Breuck[4], P. Caselli[5], B. Hatsukade[2], K. Saigo[6]
[1] *The Hakubi Center for Advanced Research, Kyoto University*
[2] *Department of Astronomy, Graduate School of Science, Kyoto University*
[3] *Cavendish Laboratory, Univerisy of Cambridge*
[4] *European Southern Observatory*
[5] *School of Physics and Astronomy, University of Leeds*
[6] *East Asian ALMA Regional Center, National Astronomical Observatory of Japan*

The chemical properties of high-z galaxies provide important information for constraining galaxy evolutionary scenarios. However, widely used metallicity diagnostics based on rest-frame optical emission lines are unusable for heavily dust-enshrouded galaxies (such as submillimeter galaxies; SMGs), especially at $z > 3$. Here we focus on the flux ratio of the far-infrared fine-structure emission lines [N II] 205μm and [C II] 158μm to assess the metallicity of high-z SMGs. Through ALMA cycle 0 observations, we have detected the [N II] 205μm emission in a strongly [C II]-emitting SMG, LESS J033229.4-275619 at $z = 4.76$. The [N II]/[C II] flux ratio is 0.043$\pm$0.008, which is similar to the ratio observed in the nearby universe ($\sim 0.02 - 0.07$). The flux ratio and photoionization models suggest that the metallicity in this SMG is consistent with solar, implying that the chemical evolution has progressed very rapidly in this system at $z = 4.76$.

Probing the State of the Ionized Medium at High-z with ZEUS and and ALMA Band-9 Early Science

Carl Ferkinhoff[1], Drew Brisbin[1], Thomas Nikola[1], Stephen Parshley[1], Gordon Stacey[1], Thomas Phillips[2], Edith Falgarone[3], Dominic Benford[4], Johannes Staguhn[4,5]
[1] *Cornell University, Ithaca, NY, USA*
[2] *Caltech, Pasadena, CA, USA* [3] *LERMA/LRA - ENS Paris, Paris, France* [4] *Goddard Space Flight Center, Greenbelt, MD, USA* [5] *Johns Hopkins University, Baltimore, MD, USA*

Using the 1st generation Redshift(z) and Early Universe Spectrometer (ZEUS-1) on the Caltech Submillimeter Observatory (CSO) we made the first detections of the [OIII] 88 μm and the [NII] 122 μm from galaxies at high redshift. We detected both lines from SMM J02399-0136 at z = 2.81 and the [NII] line from the H1413+117 (The Cloverleaf QSO) at z = 2.56. Both sources feature a broad absorption line QSO, a massive starburst, and multiple componets distributed on the sky. The sources are also well studied at other wavelengths. Based on our ZEUS-1 detections we proposed ALMA Band-9 Early Science observations of each source to spatially resolve the [NII] line as well as obtain a high resolution 120 μm rest-frame continuum map. The high spatial resolution of ALMA allows us to disentagle the excitation mechnism of the [NII] line, star formation vs. AGN, as well as indentify the nature of each component. Here we report the results of our ALMA Early Science program.

ALMA Band 7 Observations of Dense Molecular Medium in the Type-1 Active Nucleus of NGC 1097

K. Kohno[1], T. Izumi[1], D. Espada[2], S. Martin[3], K. Sheth[4], S. Matsushita[5], P. Hsieh[5], E. Schinnerer[6], K. Fathi[7], J. Turner[8], N. Nakai[9], and NGC 1097 collaboration
[1] *Univ. of Tokyo* [2] *NAOJ* [3] *ESO* [4] *NRAO* [5] *ASIAA* [6] *MPI* [7] *Stockholm Univ.* [8] *UCLA* [9] *Tsukuba Univ.*

In order to investigate the physical and chemical properties of dense molecular gas at the vicinity of active galactic nucleus (AGN), we have conducted ALMA Band 7 observations of the low-luminosity type-1 Seyfert/LINER galaxy NGC 1097 (2011.0.00108.S, PI=K.Kohno). We obtained $1''.5 \times 1''.2$ resolution images of HCN(4-3), HCO^+(4-3), and 860 μm continuum. The noise level was $\sim$ 2 mJy (for a velocity resolution of $\sim$ 8 km/s) with the on-source integration time of only $\sim$ 1 hr using 14-15 antennas in the compact configuration.
This cycle 0 observation uncovered a bright and unresolved ($< 1''.2 \times 0''.76$ or $< 84 \times 53$ pc at D=14.4 Mpc) condensation of dense molecular gas traced by HCN(4-3) and HCO^+(4-3) at the nucleus. We also find a striking enhancement of HCN(4-3)/CS(7-6) flux ratio ($>$ 10) at the nuclear dense gas condensation, and the ratio is significantly higher compared with those in starburst galaxies/star-forming regions (e.g., $\sim$3.5 in NGC 253 and $\sim$1.7 in Ori-KL). This will add further evidence for the presence of dense gas affected by AGN in NGC 1097. Full excitation analysis of these lines will be made after the delivery of the expected Band 3 data.

Solar system science with ALMA

Raphael Moreno[1], Emmanuel Lellouch[1], Dominique Bockelée-Morvan[1]
[1] *LESIA, Observatoire de Paris-Meudon, France*

Thanks to unprecedented sensitivity, angular resolution and instantaneous uv-coverage, ALMA will adress key questions that concern planets and comets.

Many new studies will be related to the general topic of the couplings between chemistry and dynamics in planetary atmospheres. It will include: (i) three-dimensional mapping of composition, temperatures and winds in the atmospheres of Mars, Venus and Titan; (ii) several aspects of Giant Planet composition and dynamics, such as the origin of oxygen, the evolution of Shoemaker Levy 9 products in Jupiter's atmosphere, and the deep atmosphere structure and meteorology; (iii) the study of tenuous and distant atmospheres (Io, Enceladus, Pluto, Triton and other Kuiper Belt objects).

Key measurements in comets on a number of topics related to the chemical and physical properties of the coma and the nucleus will be obtained. These include (1) the identification of new molecular species and measurements of key isotopic ratios, (2) measurements of the composition of short-period comets coming from the trans-Neptunian scattered disc, to investigate chemical diversity within the whole comet population, (3) imaging of gas jets and their relationship with dust features, (4) the study of extended sources of gas in the coma, (5) the study of the physical and outgassing properties of the nucleus.

Temporal monitoring of Saturn's 2011 Great Storm and its aftermath in 2011-2012 with Herschel and ALMA

T. Cavalié[1,2], B. Hesman[3], H. Feuchtgruber[4], E. Lellouch[5], R. Moreno[5], R. Achterberg[3], F. Gueth[6], T. Fouchet[5], P. Hartogh[7], A. Moullet[8]
[1] *Univ. Bordeaux, LAB, UMR 5804, F-33270, Floirac, France*
[2] *CNRS, LAB, UMR 5804, F-33270, Floirac, France*
[3] *GSFC, Univ. Maryland, USA*
[4] *Max Planck Institute for Extraterrestrial Physics, germany*
[5] *Observatoire de Paris, LESIA, France*
[6] *IRAM, France*
[7] *Max Planck Institute for Solar System Research*
[8] *NRAO, USA*

The planetary-scale storm that perturbed Saturn's atmosphere in its northern hemisphere in 2010-2011 has left a hot stratospheric vortex at 40°N, still observable as of August 2012. Cassini and ground-based observations have shown that the temperature and the chemistry of hydrocarbons have been perturbed in the vortex. Using Herschel and ALMA, we checked whether or not the oxygen species abundances and chemistry have also been modified in the vortex.
We have observed Saturn with the Herschel in July 2011, February 2012 and July 2012 to map H_2O at 66 and 67 microns and CH_4 at 120 microns with PACS and CH_4 at 159 microns with HIFI. We have also used ALMA during Cycle 0 to map CO at 230 GHz. We use the CH_4 maps as a temperature probe and the H_2O and CO maps to constrain the chemistry of oxygen species in the vortex. In this paper, we will present the observations and a preliminary analysis to illustrate the evolution of the abundances of H_2O and CO in the vortex. For instance, we inferred an increase by a factor of 50-100 of the H_2O column in the vortex with Herschel/PACS in July 2011 in a preliminary analysis.

Protoplanetary and debris disks

Michiel R. Hogerheijde[1]
[1] *Leiden Observatory, Leiden University, PO Box 9513, 2300 RA, Leiden, The Netherlands.*
michiel@strw.leidenuniv.nl

ALMA is revolutionizing the study of both planet-forming disks and of debris disks that may already harbor full-fledged planetary systems. In this talk I will review our current understanding of these disks and outline the major questions that remain to be answered. Since their first direct imaging three decades ago, circumstellar disks have been studied at wavelengths from the radio to the ultraviolet. Much that we know about disks was learned using infrared telescope on the ground and in space, and with pioneering millimeter interferometers in the French and Japanese Alps, in California and on Hawaii. However, to date the disks have hold on to their two deepest secrets: how do planets form? and how are debris belts and young planetary systems related? ALMA is poised to make major steps forward in unlocking these secrets, and I will conclude with a brief tour of some of the spectacular results on disks that this first year of ALMA science has already produced.

Structure of Transitional Disks as Revealed by ALMA

Laura M. Pérez[1], John Carpenter[2], Andrea Isella[2], Anneila Sargent[2]
[1] *NRAO*
[2] *Caltech*

A small fraction of circumstellar disks show a remarkable deficit of infrared flux – indicative of a dust-depleted inner cavity – while substantial emission at longer wavelengths points to the presence of a massive outer disk. These so-called "transitional disks" are thought to represent a brief, but extremely important, evolutionary phase between young, optically thick protoplanetary disks and old, optically thin debris disks. We present the first 450 μm (Band 9) ALMA observations of dust continuum emission from transitional disks in the nearby Taurus and ρ-Ophiuchus star-forming regions. These disks were selected because they possess large inner cavities and show little evidence for stellar-mass companions. With ALMA's exquisite sensitivity and high angular resolution already available in Early Science, ($\sim 0.2'' - 0.3''$, $\sim 25 - 40$ AU at the distance of these objects), the inner cavities and outer regions are resolved. Additionally, we obtained observations in the CO(J = 6-5) transition, to investigate the presence of gas inside the dust-depleted cavities and the extent of the outer gaseous disk. These ALMA Early Science observations provide an unique opportunity to study the structure of disks with possible planetary companions.

Planet formation in action: resolved gas and dust images of a transitional disk and its cavity

N. van der Marel[1], E.F. van Dishoeck[1,2], S. Bruderer[2], T.A. van Kempen[1,3], M. Schmalzl[1], J.M. Brown[4], G.S. Mathews[1],K.M. Pontoppidan[5], V.C. Geers[6], G.J. Herczeg[7]
[1] *Leiden Observatory, Leiden University, the Netherlands*
[2] *MPE, Garching, Germany*
[3] *Joint ALMA Office, Santiago, Chile*
[4] *CfA, Boston, USA*
[5] *STScI, Baltimore, USA*
[6] *ETH, Zurich, Switzerland*
[7] *Beijing University, Beijing, China*

A central question in planet formation is how the optically thick protoplanetary disks around classical T Tauri stars evolve into the optically thin debris disks around older systems. The best test of formation scenarios is observing systems that are actively forming planets: the transitional disks with large inner dust cavities. We present the first results of our ALMA Cycle 0 program using Band 9, imaging the Herbig Ae star Oph IRS 48 in CO 6–5, $C^{17}O$ 6–5 and the submillimeter continuum in the extended configuration. The resulting $\sim$0.2$''$ spatial resolution completely resolves the cavity of this disk in the gas. The huge leap in sensitivity provided by ALMA at high frequencies allows a large dynamic range of gas masses inside the cavity to be tested. The gas surface density inside the cavity of IRS 48 is at least two orders of magnitude lower than the gas in the surrounding ring. On the other hand, the continuum emission reveals an unexpected huge asymmetry and steep edges in the dust distribution along the ring suggestive of dust trapping. We will discuss the implications of the combined gas and dust distribution for planet formation at a very early stage. This is the first transitional disk with spatially resolved gas inside the dust cavity, demonstrating the superb capabilities of the Band 9 receivers.

An ALMA investigation of proto-planetary disks around young Brown Dwarfs

Luca Ricci[1], L. Testi[2,3], A. Natta[3,4], A. Scholz[4], I. de Gregorio-Monsalvo[5]
[1] *California Institute of Technology, Pasadena CA, USA*
[2] *European Southern Observatory, Garching, Germany*
[3] *INAF-Osservatorio Astrofisico di Arcetri, Firenze, Italy*
[4] *School of Cosmic Physics, Dublin Institute for Advanced Studies, Dublin, Ireland*
[5] *Joint ALMA Observatory/European Southern Observatory, Santiago, Chile*

Observations of proto-planetary disks at sub-mm wavelengths trace mm-sized pebbles and molecular gas in the disk outer regions. Models of dust evolution including grain growth and radial migration in gas-rich disks can therefore be tested by these data. I will present the results from an ALMA project aimed at characterizing grain growth to mm-sized grains and molecular gas in disks around young Brown Dwarfs. I will show how our ALMA data critically challenge the current models of the early stages of planet formation. We also detected cold molecular CO gas from the disk surrounding ρ Oph 102. This indicates that Brown Dwarf disks can be gas-rich, similarly to what is typically found for disks around young Solar-like stars. Finally, I will show how future ALMA observations of proto-planetary disks at very high angular resolution and sensitivity will greatly inform models of planetesimal formation by investigating the spatial distribution of mm-sized grains in the disk.

Keplerian disk formation around protostars

Nagayoshi Ohashi[1], Hsi-Wei Yen[2], Shigehisa Takakuwa[2], Kohji Tomisaka[1], Kengo Tomisaka[3],Masahiro Machida[4], Yuri Aikawa[5], Kazuya Saigo[1], Masao Saito[1], Masa Hayashi[1]
[1] *NAOJ*
[2] *ASIAA* [3] *Princeton Univ.* [3] *Kyushu Univ.* [3] *Kobe Univ.*

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

We have been observing protostars deeply embedded in infalling envelopes with SMA, revealing possible transition from infalling motions to Keplerian motions in the inner regions of infalling envelopes. In order for us to clearly demonstrate Keperian disk formation around these protostars, we have carried out ALMA cycle 0 in C18O J=2-1. In this talk, we will briefly review our SMA observations showing possible transitions from infalling motions to Keplerian motions, and then present our ALMA results to clearly demonstrate disk formation around protostars.

Unveling the gas and dust disk structure in HD163296 using ALMA observations

I. de Gregorio-Monsalvo[1], P. Klaassen[2], L. Testi[3], M. Rawlings[4], F. Menard[5], W. Dent[1], C. Pinte[6], S. Takahashi[7] , A. Hales[1] , E. Chapillon[7], E. Akiyama[8], D. Espada[8] , P. Cortes[1] , C. Lopez[1] , K. Tachihara[1] , A. Higuchi[1] , S. Corder[1], G. Mathews[2], A. Juhasz[2] , L. Nyman[1] , N. M. Phillips[1] , J. A. Rodón[9] , M. Saito[1] , T. Van Kempen[1]

[1] *Joint ALMA Observatory, Chile*, [2] *Leiden Observatory, The Netherlands*, [3] *European Southern Observatory, Germany*, [4] *National Radio Astronomy Observatory, USA*, [5] *UMI-FCA, CNRS / INSU France , and Dept. de Astronomia, U de Chile*, [6] *CNRS / UJF Grenoble, France* , [7] *ASIAA, Taiwan*, [8] *NAOJ, Japan*, [9] *European Southern Observatory, Chile*

Dust and gas-rich disks around recently-formed stars are important as they harbor planets either recently or possibly still in the process of forming. Consequently the structure of these young protoplanetary disks has been the subject of intense study over a wide range of wavelengths. HD163296 is one of the best-studied protoplanetary disks, and was one of the first to be resolved with mm interferometry. The brightness of this source in mm molecular lines has made HD163296 an excellent laboratory for comparing with disk models, provoking studies of radial and vertical temperature and molecular abundances. Previous interferometric observations at mm-wavelengths have provided images a few resolution elements across, but hitherto do not provide detailed images. In this work we present the detailed radial and vertical structure of this protoplanetary disk using CO (3-2) ALMA data in extended configuration ($\sim$ 0.5” spatial resolution). We infer accurate physical parameters from both continuum and molecular line emission that helps to break the degeneracy of the models and better constrain the underlying disk structure. These data have been part of a Science Verification project (2011.0.000010.SV) aiming to test ALMA mixed correlator modes.

ALMA estimate of the gap depth in the HD142527 protoplanetary disk

Sebastian Perez M.[1], Pablo Roman[1] and Simon Casassus[1]

[1] *Universidad de Chile*

Radial gaps in gas-rich protoplanetary disks are tantalizing evidence for the process of planet formation. As planets form and grow within their disks, dynamical planet-disk interactions lead to angular momentum exchanges and to radical changes in the disk’s otherwise smooth surface density. The Atacama Large Milimeter Array (ALMA) has the necessary sensitivity and resolution to map such protoplanetary gaps. Our case study, the gas rich massive disk around HD142527, features a very large gap that extends up to 140 AU from the central star, and a massive outer disk. We report on ALMA Cycle 0 band-6 observations of HD142527’s gap. Our goal is to quantify the depth of the planet-carved gap. We use a combination of radiative transfer modelling and image synthesis techniques to compare the observations against our models in the uv plane, hence bypassing the need of applying a CLEAN or other image reconstruction algorithm. **Important:** The Cycle 0 data are embargoed until Jan 3. This abstract is pending authorization from ALMA observatory, and cannot be included in the conference programme ahead of the conference. If scheduled, the authors will provide abbreviated title and abstract for the programme, and will add a mention in the sense that full information will be provided at the conference.

Galaxies in the Local Universe

Christine D. Wilson[1]
[1] *McMaster University*

Galaxies in the local universe allow us to study physical and chemical processes and environments that are not common in our own Galaxy. The key is to achieve sufficient spatial resolution to isolate interesting objects and regions, along with sufficient sensitivity to study them in detail. ALMA's combination of high angular resolution, sensitivity, and spectral coverage promises to revolutionize our understanding of galaxies in the local universe. In my talk, I will discuss the expected contribution of ALMA to the study of star formation and the molecular interstellar medium in galaxies, as well as the promise of ALMA for studying molecular gas and dust that is impacted by and possibly feeding central massive black holes. I will also touch on emerging research areas driven by the new capabilities of ALMA, such as the potential for using free-free emission and radio recombination lines to trace the star formation rate, and the use of rarer molecular species to trace physical and chemical conditions in galaxies.

Molecular gas properties of M100 with ALMA

C. Vlahakis[1,2], S. Leon[1,2], G. Bendo[3], D. Garcia[1,2], S. Martin[2], M. Zwaan[4]
[1] *Joint ALMA Observatory, Alonso de Cordova 3107, Santiago, Chile.*
[2] *European Southern Observatory, Alonso de Cordova 3107, Santiago, Chile.*
[3] *ALMA Regional Centre Node, Jodrell Bank Centre for Astrophysics, University of Manchester, UK.*
[4] *European Southern Observatory, Karl Schwarzschild str. 2, Garching, Germany.*

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

Giant Molecular Clouds and Star Formation in the Tidal Molecular Arm of NGC 4039

D. Espada[1], S. Komugi[1,2], E. Muller[1], K. Nakanishi[1,2,3], M. Saito[1,2], K. Tatematsu[1], S. Iguchi[1], T. Hasegawa[1,2], N. Mizuno[1,2], D. Iono[1,4], S. Matsushita[2,5], A. Trejo[5], E. Chapillon[5], S. Takahashi[5], Y.N. Su[5], A. Kawamura[1], E. Akiyama[1], M. Hiramatsu[1], H. Nagai[1], R. E. Miura[1], Y. Kurono[1], T. Sawada[1,2], A. E. Higuchi[1,2], K. Tachihara[1,2], K. Saigo[1], T. Kamazaki[1,2]

[1]*National Astronomical Observatory of Japan (NAOJ), 2-21-1 Osawa, Mitaka, Tokyo 181-8588, Japan*
[2]*Joint ALMA Observatory, Alonso de Cordova 3107, Vitacura, Santiago 763-0355, Chile*
[3]*The Graduate University for Advanced Studies (SOKENDAI), Department of Astronomical Science, 2-21-1 Osawa, Mitaka, Tokyo 181-8588, Japan*
[4]*Nobeyama Radio Observatory, NAOJ, Minamimaki, Minamisaku, Nagano, 384-1305, Japan*
[5]*Academia Sinica, Institute of Astronomy and Astrophysics, P.O. Box 23-141, Taipei 10617, Taiwan*

The properties of tidally induced arms provide a means to study molecular cloud formation and the subsequent star formation under environmental conditions which in principle are different from quasi stationary spiral arms. We report the properties of a newly discovered molecular gas arm of tidal origin at the south of NGC 4039 and the overlap region in the Antennae galaxies, using the Atacama Large Millimeter/submillimeter Array (ALMA) science verification CO(2–1) data. It extends 3.4 kpc (34″) and is characterized by a width of $<$ 200 pc (2″), slightly narrower than a typical spiral arm, and velocity widths of typically ΔV = 10–20 km s^{-1}. About 10 clumps are strung out along this structure, most of them unresolved, with average surface densities of $\Sigma_{\rm gas} \simeq$ 10–100 M$_\odot$ pc^{-2}, and masses of (1–8)$\times$10^6 M$_\odot$. These structures resemble the morphology of beads on a string, with an almost equidistant separation between the beads of about 350 pc, which may represent a characteristic separation scale for giant molecular cloud formation. We find that the star formation efficiency at a resolution of 6″ (600 pc) is in general a factor 10 higher than in disk galaxies and other tidal arms and bridges.

ALMA and Spitzer Observations of the Spectacular Circumnuclear Ring and Starburst in the Barred Spiral NGC 1097

K. Sheth[1], N. Kimani[1], K. Kohno[2], S. Martin[3]
[1]*National Radio Astronomy Observatory*, [2] *University of Tokyo*, [3] *European Southern Observatory*

Bars drive molecular gas and dust from the disk of the galaxy to the center where they accrete in beautiful kiloparsec scale circumnuclear starburst rings. These rings form stars at rates 10–100$\times$ the average activity in the disk and offer a unique laboratory for the study of star formation. We have imaged the CO, HCN, HCO$+$ and dust continuum emission in the central ring and nucleus in the nearby barred spiral NGC 1097 using bands 3 and 7 with ALMA in Cycle 0. We also imaged the ring using the IRS spectrograph on Spitzer in several transitions of the warm molecular gas in H_2, poly-aromatic hydrocarbon lines at 6.3 and 11.6μm and atomic lines such as [NeII], [NeIII], and [SiII]. Together these data offer us a unique opportunity to understand the complex interplay between star formation and the molecular gas and dust environment. I will discuss the physical conditions in this ring in context of the star formation activity - specifically, the density and fraction of the warm and cold molecular gas, the hardness of the radiation field and the relationship between the PAH emission and the molecular gas. I will also show the spectacular movement of the molecular gas across the LINER nucleus in this galaxy which offers us, for the first time, a detailed view of the environment around a nearby black hole.

Imaging the Nearest Circumnuclear Starburst: ALMA observes NGC 253

Alberto D. Bolatto[1], Fabian Walter[2], Adam K. Leroy[3], Steven R. Warren[1], Martin Zwaan[4], Sylvain Veilleux[1], Eve Ostriker[5], Juergen Ott[6], Jacqueline Hodge[2], Axel Weiss[7], Nick Scoville[8], and Erik Rosolowsky[9]

[1] *Department of Astronomy, University of Maryland, College Park, Maryland, USA*
[2] *Max-Planck Institut für Astronomie, Heidelberg, Germany*
[3] *National Radio Astronomy Observatory, Charlottesville, Virginia, USA*, [4] *European Southern Observatory, Garching, Germany*, [5] *Department of Astrophysical Sciences, Princeton University, Princeton, New Jersey, USA*, [6] *National Radio Astronomy Observatory, Socorro, New Mexico, USA*, [7] *Max-Planck Institut für Radioastronomie, Bonn, Germany*, [8] *Department of Astronomy, California Institute of Technology, Pasadena, California, USA*, [9] *Department of Physics, University of British Columbia, Okanagan, Canada*

We have used ALMA to image NGC 253, the nearest circumnuclear starburst, in CO and high-dipole molecules. These observations detect and map, for the first time: 1) the molecular component in the galactic superwind emanating from its nuclear regions, and 2) the dense gas structures in the starburst at a resolution of ~ 20 pc. These observations provide the first glimpse of the processes entraining molecular gas in a starburst-driven galactic outflow, as well as a resolved measure of the mass loading of the wind. In particular, we see an association between the out-of-plane molecular gas emission and molecular expanding shell structures apparent in the central disk. These observations provide the first measurements of the resolved giant molecular cloud properties (the Larson relations) in the core of a starburst in HCO^+, HCN, and CS, as well as allowing an estimation of their densities. The ALMA observations include a number of other transitions in the passband, encompassing detections of H40α, $C^{17}O$, CCH, CN, SO_2, and other molecules. They present a very rich dataset that we are only beginning to explore.

ALMA Imaging of the Most Luminous Galaxy within z=0.01

Kazushi Sakamoto[1], Susanne Aalto[2], Francoise Combes[3], Aaron Evans[4], Alison Peck[5]
[1] *ASIAA*, [2] *Chalmers U. of Technology*, [3] *Paris Observatory*, [4] *NRAO/U. Virginia*, [5] *NRAO*

We have been observing with ALMA the most luminous galaxy at $z \leq 0.01$, the luminous infrared merger NGC 3256 ($D = 40$ Mpc, $L_{\rm bol} = 4 \times 10^{11} L_\odot$). Despite its prominence this southern galaxy had been lacking high-resolution millimeter/submillimeter observations before the advent of ALMA, except for our SMA observations at low elevations (≤26°!). Our main targets are the double nuclei with a 1 kpc (5") separation and the high-velocity molecular gas in the central region. The former nuclei can be regarded as a younger state of the twin nuclei in Arp 220, allowing us a comparative study of the circumnuclear molecular gas in late-stage luminous mergers. The latter was first found with the SMA and attributed to a massive molecular outflow (Sakamoto, Ho, Peck 2006, ApJ, 644, 862). ALMA CSV data revealed it to be $>$1000 km s^{-1}-wide (Sakamoto 2011, arXiv:1207.3678) and we expect our Cycle 0 data to unveil its full spatial and kinematical structure. We are using Band 3 and 7, to complement our SMA CO(2−1) data, and both compact and extended configurations. With the compact-configuration data already at hand and extended-configuration data coming soon, we are assessing the dynamical and physical properties of the molecular gas in the merger to uncover the interplay between the ISM and the high luminosity nuclei, a key process in the merger-induced galaxy evolution. We will report our latest findings.

An ALMA and ATCA Molecular Line Survey toward Centaurus A

Jürgen Ott[1], David Meier[2], Mark McCoy[2], Sebastien Muller[3], Alison Peck[1], Violette Impellizzeri[1], Fabian Walter[4], Susanne Aalto[3], Christian Henkel[5], Sergio Martin[6], Paul van der Werf[7], Ilana Feain[8]

[1]*National Radio Astronomy Observatory*, [2]*New Mexico Intitute for Mining and Technology*, [3]*Chalmers University*, [4]*Max-Planck-Institut für Astronomie*, [5]*Max-Planck-Institut für Radioastronomie* , [6]*ESO Santiago*, [7]*Leiden University*, [8]*CSIRO Astronomy and Space Science*

We present Atacama Large Millimeter/submillimeter Array and Australia Telescope Compact Array data of molecular absorption lines toward the bright central core of Centaurus A. The line of sight crosses the prominent dust lane and continues through the disk and eventually through gas that may be very close to the central supermassive black hole. The goal of our the survey is to determine the physical conditions of the gas via analyses of molecular line tracers including molecular abundances and excitation conditions that are sensitive to changes in temperature, density, ionization, and shocks. This study allows us to derive the physical conditions of each absorption line complex and allows us to define the main process shaping its environment. We target lines in the 13, 7, 3, and 1mm wavebands including CO isotopes, HCN, HNC, N_2H^+, HCO^+, CCH, SiO, H_2O, NH_3, HNCO, H_2CO, and others. A first analysis of our data shows the complex nature of the spectrum, with very narrow ($<\sim 0.5$ km s^{-1}), broad (~ 50 km s^{-1}) and mixed broad and narrow features. All absorption components show peculiar molecular line ratios. Overall, the broad component appears to be denser, more excited and more influenced by high energy photons. The velocities are up to ~ 80 km s^{-1} offset to systemic which suggests that the broad component traces material that either orbits the super-massive black hole or is the signature of infalling gas that may directly fuel the black hole activity. We also provide evidence for molecular lines possibly tracing directly the black hole accretion disk.

Zooming in on Molecular Clouds in 30 Doradus

Rémy Indebetouw[1,2], Crystal Brogan[2], Suzanne Madden[3], Margaret Meixner[4], Adam Leroy[2], Todd Hunter[2], Kelsey Johnson[1], Nick Abel[5], Jean-Philippe Bernard[6], Diane Cormier[3], Frederic Galliano[3], Eric Herbst[1], Sacha Hony[3], Annie Hughes[7], Akiko Kawamura[8], Amanda Kepley[2], Vianney Lebouteiller[3], Erik Muller[9], Joana Oliveira[10], Toshikazu Onishi[8], Xander Tielens[11], Tatiana Vasyunina[1], Barbara Whitney[12], Mark Wolfire[13], Ronin Wu[3]

[1] *University of Virginia*, [2] *National Radio Astronomy Observatory*, [3] *CEA Saclay*, [4] *Space Telescope Science Institute*, [5] *University of Cincinnati*, [6] *CESR*, [7] *MPIA*, [8] *University of Nagoya*, [9] *NAOJ*, [10] *University of Keele*, [11] *Leiden University*, [12] *University of Wisconsin*, [13] *University of Maryland*

30 Doradus in the Large Magellanic Cloud is the nearest super-star cluster, and thus is an ideal laboratory in which to study the impact of extreme star formation on the molecular gas in galaxies. We present observations of the northern molecular cloud in 30 Doradus using three isotopologues of CO(2-1). These data reveal complex filamentary molecular gas structures, and for the first time in an extragalactic extreme environment, we resolve the parsec-scale dense clumps that actually participate in star formation. The mapped region spans a large range of incident radiation field, from photoablated pillars on the edge of the HII region to clumps in relatively shielded regions 20 parsecs deeper in the cloud. In combination with Spitzer, Herschel, and other data, we can obtain a highly detailed picture of physical conditions in a real starburst PDR at reduced metallicity for the first time. These detailed studies are important to inform the interpretation of many ALMA observations of PDRs, star formation and molecular gas in more distant galaxies. Complementary data revealing the dense molecular gas from ALMA HCO^+, HCN, and CS observations will also be presented in a separate submission.

ALMA Observations of 30 Doradus: Dense Gas Tracers HCO+, HCN, and CS

Crystal Brogan[1], Rémy Indebetouw[1,2], Suzanne Madden[3], Margaret Meixner[4], Adam Leroy[1], Todd Hunter[1], Kelsey Johnson[2], Nick Abel[5], Jean-Philippe Bernard[6], Diane Cormier[3], Frederic Galliano[3], Eric Herbst[2], Sacha Hony[3], Annie Hughes[7], Akiko Kawamura[8], Amanda Kepley[1], Vianney Lebouteiller[3], Erik Muller[9], Joana Oliveira[10], Toshikazu Onishi[8], Xander Tielens[11], Tatiana Vasyunina[2], Barbara Whitney[12], Mark Wolfire[13], Ronin Wu[3]

[1] *National Radio Astronomy Observatory*, [2] *University of Virginia*, [3] *CEA Saclay*, [4] *Space Telescope Science Institute*, [5] *University of Cincinnati*, [6] *CESR*, [7] *MPIA*, [8] *University of Nagoya*, [9] *NAOJ*, [10] *University of Keele*, [11] *Leiden University*, [12] *University of Wisconsin*, [13] *University of Maryland*

As the nearest super-star cluster 30 Doradus in the Large Magellanic Cloud presents a truly unique opportunity to study star formation in an extreme environment at high angular resolution. We will present $2''$ (~ 0.5 pc) resolution ALMA observations of the molecular cloud North of R136 in the 3mm lines of HCO+, HCN, and CS. The sensitivity of ALMA allows us to spatially resolve the dense gas that actually participates in star formation for the first time in a reduced metallicity extragalactic starburst. Complementary ALMA observations of CO (2-1) and its isotopologues will also be presented in a separate submission. These observations reveal filamentary cloud structures, as well as dense clumps ~ 1 pc in size coincident with embedded near-IR sources. We will present a detailed analysis of the physical conditions in these star-forming clumps. The results from this study will be invaluable for extrapolation to unresolved observations in the distant Universe.

Probing the Galactic Centre with ALMA: The Final Frontier

A. P. Rushton[1,2,3], C. Brinkerink[4], H. Falcke[4,5,6], D. Barkats[7], G. C. Bower[8], A. Brunthaler[6,9], C. Gammie[10], V. Impellizzeri[7,9], S. Markoff[11], M. Moscibrodzka[12], K. Menten[6], A. Peck[7,9], R. Schaaf[13], M. Wright[8]

[1]*European Southern Observatory*, [2]*University of Southampton*, [3]*Onsala Space Observatory*, [4]*Radboud University Nijmegen*, [5]*ASTRON*, [6]*Max-Planck-Institut für Radioastronomie*, [7]*Joint ALMA Observatory*, [8]*University of California, Berkeley*, [9]*National Radio Astronomy Observatory*, [10]*University of Illinois*, [11]*University of Amsterdam*, [12]*University of Nevada*, [13]*University of Bonn*

We present the first ALMA observations taken towards the Galactic Centre (Sgr A*) with the science verification program and during cycle-0. The Galactic Centre contains the best-constrained supermassive black hole candidate of approximately 4×10^6 solar masses. The mass is centred on the compact non-thermal radio source Sgr A* that is likely produced from an accretion disk or an outflowing jet. The overall luminosity peaks at sub-millimetre wavelengths, suggesting a turn-over of optically thick to thin synchrotron radiation and its size shrinks with increasing frequency, exhibiting a clear size-frequency relationship. By combining the size and timing measurements, we aim to measure the flow speed and direction of magnetised plasma. Measurements were taken in Frequency Division Mode (FDM) to observe the hydrogen recombination lines and in Time Division Mode (TDM) to near simultaneously observe three different wavelengths using the method of quickly switching between bands 3, 6 and 7. We have extracted the continuum emission from the core of Sgr A* and will search for both intra and inter-band delays and correlations with other observatories. The principal aim is to show a clear time lag from high to low frequencies following a flare in the overall luminosity.

Seeing Stars with ALMA: Millimeter and Sub-Millimeter Probes of Stars and Stellar Evolution

R. A. Osten[1]
[1] *Space Telescope Science Institute, Baltimore, MD USA*

The ALMA facility holds significant promise for the study of stellar atmospheres and stellar evolution. Observations of chromospheric emission in both the Sun and active stars will provide refinements to atmospheric models and constrain the fraction of unresolved stellar disk covered in dense plasma threaded with magnetic fields. Transient mm/sub-mm variations point to the presence and action of very high energy particles in stellar atmospheres. Spatial resolution of continuum emission from evolved stars will be used to investigate mass loss mechanisms in late-type stars. The temperature and density structure in the dust formation zone around evolved late-type stars can be probed with line and continuum emission. The role played by high-velocity winds in shaping the envelopes of asymptotic giant branch stars during the proto-planetary nebulae phase will be investigated, as well as the unique atomic and molecular chemistry revealed through line surveys in proto-planetary nebulae. Continuum emission from pulsar wind nebulae can provide information about the ambient magnetic field and the pulsar wind. The spatial distribution of line emission from shocked and unshocked gas around supernova remnants leads to determination of gas properties across the shock front, revealing how these stellar remnants affect the global properties in a galaxy. This talk will set the stage for ALMA's contribution in this broad science topic, by providing context and highlighting key questions that can and will need to be addressed with ALMA.

Investigating the coldest object in the Universe: ALMA observations of the Boomerang Nebula

R. Sahai[1], W. Vlemmings[2], L-Å Nyman[3], P. Huggins[4]
[1] *Jet Propulsion Laboratory, Caltech, Pasadena, USA*
[2] *Onsala Space Observatory, Onsala, Sweden*
[3] *Joint ALMA Observatory, Santiago, Chile*
[4] *New York University, New York, USA*

The Boomerang Nebula is the coldest known object in the Universe, and an extreme member of the class of Pre-Planetary Nebulae, objects which represent a short-lived transitional phase between the AGB and Planetary Nebula evolutionary stages. The Boomerang's estimated prodigious mass-loss rate (0.001 $M_\odot$ yr^{-1}) and low-luminosity (300 $L_\odot$) lack an explanation in terms of current paradigms for dusty mass-loss and standard evolutionary theory of intermediate-mass stars. Single-dish CO J=1-0 observations (with a $45''$ beam) show that the high-speed outflow in this object has cooled to a temperature significantly below the temperature of the cosmic background radiation. We report on our high-resolution ALMA mapping of the CO lines in this ultra-cold nebula to determine the origin of these extreme conditions and robustly confirm current estimates of the fundamental physical properties of its ultra-cold outflow. Two exciting and unanticipated results are the discovery of large (mm-sized) grains in the dense nebular waist and the detection of emission regions beyond the ultracold envelope which indicate the re-warming of the cold gas, most likely due to photoelectric grain heating.

Unwinding the secrets of thermal pulses and sculpted winds in AGB stars with ALMA

Maercker, M.[1,2], Mohamed, S.[2,3], Vlemmings, W.H.T.[4], Ramstedt, S.[2], Groenewegen, M.A.T.[5], Humphreys, E.[1], Kerschbaum, F.[6], Lindqvist, M.[4], Olofsson, H.[4], Paladini, C.[6], Wittkowski, M.[1], de Gregorio-Monsalvo, I.[7], Nyman, L.-A.[7]
[1]*European Southern Observatory Garching*, [2]*Argelander Institute for Astronomy, University of Bonn*, [3]*South African Astronomical Observatory*, [4]*Onsala Space Observatory, Chalmers University of Technology*, [5]*Royal Observatory of Belgium*, [6]*University of Vienna*, [7]*Joint ALMA Observatory*

I will present ALMA Cycle 0 observations of the CO emission around the carbon AGB star R Sculptoris. The observations show the detached shell and circumstellar medium around this star in unprecedented detail, and demonstrate the power of ALMA already during the first cycle of operations. The detached shell is formed due to the change in mass-loss rate and expansion velocity during a thermal pulse. Amazingly, the data also reveal a clear, and previously unobserved, spiral structure within and connected to the detached shell, indicating the presence of a companion star or high-mass planet. Combined with 3-dimensional hydrodynamical models, we for the first time set direct observational constraints on the changes in mass-loss rate and expansion velocity during and after a thermal pulse. By modelling the stellar wind from a binary system, we show that the observed spiral constrains the mass-loss rate and expansion velocity, the duration of the pulse, and the companion mass. The results imply a change in pulse to post-pulse mass-loss rate by a factor of 30, and a gradual decrease of the expansion velocity. We are thus able to uncover the record of mass-loss throughout the thermal-pulse cycle in unprecedented detail. The results usher in a new paradigm in our understanding of this fundamental period of stellar evolution, and the implications it has for the chemical evolution of evolved stars, the ISM, and galaxies.

Emission by rotational transitions of CO and SiO in the Inner Debris of Supernova 1987A

Julia Kamenetzky[1], Richard McCray[1], Remy Indebetouw[2,3], M. J. Barlow[4], Mikako Matsuura[4], Catherine Vlahakis[5], Maarten Baes[6], Margaret Meixner[7,8], Alberto Bolatto[9]
[1]*University of Colorado, Boulder*, [2]*University of Virginia* [3]*National Radio Astronomical Observatory* [4]*University College London* [5]*Joint ALMA Observatory* [6]*Universiteit Gent* [7]*Space Telescope Science Institute* [8]*Johns Hopkins University* [9]*University of Maryland*

We present the first detection of millimeter molecular lines from a supernova remnant with rotational emission lines of CO (J=1-0 and J=2-1), ^{28}SiO and ^{29}SiO (J=5-4) from SN1987A using ALMA Cycle 0. The high angular resolution and line width (FWHM ~ 2200 km/s) indicate that the emission originates in the inner debris. We interpret our observations with a simplified model in which the emitting CO resides in carbon/oxygen clumps of uniform density and temperature within an expanding sphere of comoving velocity ~ 1500 km/s. The CO has a current mass $M_{CO} \sim 0.02$ $M_{\odot}$ ($\sim$ 25 times larger than estimates from CO vibrational emission at early times) and temperature $T_{CO} \sim 50-100$K and occupies a fraction $f \sim 0.2$ of the emitting volume. We predict that the luminosity in the J = 3-2 transition of CO will be $\sim 3-5$ times that of the J = 2-1. A *Herschel* SPIRE-FTS spectrum yields upper limits which do not constrain our models. Future images across the line profiles will give us an unprecedented opportunity to map the structure and composition of the inner debris in three dimensions with angular resolution comparable to that of the Hubble Space Telescope.

Resolving (sub)Millimeter Emission From SN1987A

Jon Marcaide[1], Rémy Indebetouw[2,3], Richard McCray[4], Mikako Matsuura[5], Ivan Martí-Vidal[6], Lister Staveley-Smith[7,8], Giovanna Zanardo[7], Michael Barlow[5], Milica Andjelić[9], Bojan Arbutina[9], Maarten Baes[10], Alberto Bolatto[11], Patrice Bouchet[12], David Burrows[13], Roger Chevalier[2], Geoffrey Clayton[14], Eli Dwek[15], Bryan Gaensler[8,16], Julia Kamenetzky[4], Robert Kirshner[17], Masa Lakićević[18], Knox Long[19], Peter Lundqvist[20], Margaret Meixner[19,21], Chi-Yung Ng[22], Masaaki Otsuka[23], Sangwook Park[24], Toby Potter[7], Karin Sandstrom[25], Alicia Soderberg[17], George Sonneborn[15], Dejan Urošević[9], Jacco van Loon[26], Catherine Vlahakis[27], Roger Wesson[28], Vladimir Zeković[9]

[1] *Universidad de Valencia*, [2] *University of Virginia*
[3] *National Radio Astronomy Observatory*, [4] *University of Colorado*
[5] *University College London*, [6] *Onsala Space Observatory*
[7] *ICRAR*, [8] *CAASTRO*
[9] *University of Belgrade*, [10] *Ghent University*
[11] *University of Maryland*, [12] *CEA Saclay*
[13] *Pennsylvania State University*, [14] *Louisiana State University*
[15] *NASA GSFC*, [16] *University of Sydney*
[17] *Harvard University*, [18] *ESO*
[19] *STScI*, [20] *Stockholm University*
[21] *Johns Hopkins University*, [22] *McGill University*
[23] *ASIAA*, [24] *University of Texas Arlington*
[25] *MPIA*, [26] *Keele University*
[27] *Joint ALMA Observatory*, [28] *University College London*

Supernovae are critical engines of insterstellar feedback, accelerating energetic particles in their shocks, and serving as fundamental producers of elements and dust. SN1987A is the only modern supernova close enough to resolve and directly observe the temporal growth of the ejecta. Even in early science, ALMA observations of SN1987A's continuum from 3mm to 850μm can separate and study emission from the inner ejecta and shocked ring. We present the first resolved images of SN1987A at 1mm and 850μm, revealing the spectral energy distribution of the shock ring at three wavelengths, and clearly resolving newly formed dust in the inner ejecta. Line emission from CO 1-0, CO 2-1, SiO 5-4, and ^{29}SiO 5-4 are also detected in the inner ejecta, and will be discussed in detail in a separate presentation at this meeting. Data such as these which resolve emission from dust and molecules forming in supernova remnants place important constraints on the ejecta physical conditions, radioactive chemistry, nucleosynthesis, and dust formation.

Part two

Posters*

* Poster abstracts appear in alphabetical order of the first author's last name

An observational study of the temperature and surface density structures of the protoplanetary disk around HD163296

E. Akiyama[1], D. Espada[1], E. Chapillon[2], S. Takahashi[2], Y. Kitamura[3], I. de Gregorio-Monsalvo[4], P. Klaassen[5], L. Testi[6], M. Rawlings[7], F. Menard[8], W. Dent[4], C. Pinte[8], A. Hales[4], P. Cortes[4], C. Lopez[4], K. Tachihara[4], A. Higuchi[4], S. Corder[4], G. Mathews[5], A. Juhasz[5], L. Nyman[4], N. M. Phillips[4], J. Rodon[9], M. Saito[4], T. van Kempen[4]

[1] *NAOJ, Japan*, [2] *ASIAA, Taiwan*, [3] *JAXA/ISAS, Japan*, [4] *JAO, Chile*, [5] *Leiden Observatory, The Netherlands*, [6] *ESO, Germany*, [7] *NRAO, USA*, [8] *UJF-Grenoble 1 / CNRS-INSU*, [9] *ESO, Chile*

We present the vertical temperature and radial surface density structures of the protoplanetary disk around the Herbig Ae star HD163296 based on ^{12}CO(J=1–0), ^{13}CO(J=1–0), and C^{18}O(J=1–0) emissions obtained from NRO 45m single-dish observations, ^{12}CO(J=2–1), ^{13}CO(J=2–1), and C^{18}O(J=2–1) from the ALMA Science Verification (SV) band 6 data, and ^{12}CO(J=3–2) and ^{13}CO(J=3–2) from the SV band 7 data and ASTE 10m single-dish observations. Double-peaked profiles are seen in all lines and fitted by the similarity solution in the standard accretion disk model. Our modeling succeeds in describing simultaneously these data by a single set of parameters (disk radius, temperature and surface density at specified distance). Using different heights of the photospheres corresponding to each CO line, we will verify that the uppermost temperatures are higher than those in the disk interior. As the similarity solution model could be one of the most suitable for describing the radial surface density structure, we will study whether the HD163296 disk evolves by transferring angular momentum outwards via viscous diffusion and confirm that primordial disks around Herbig Ae stars have diffuse gas in the outer regions with the surface density exponentially decreasing with radius.

A $\lambda = 3$ mm molecular line survey of NGC 1068. Chemical signatures of an AGN environment.

Rebeca Aladro[1,2], Serena Viti[2], Estelle Bayet[3], Denise Riquelme[4],Sergio Martín[1], Rainer Mauersberger[5], Jesús Martín-Pintado[6], Miguel Ángel Requena-Torres[4], Carsten Kramer[7], Axel Weiß[4]

[1] *ESO, Chile*, [2] *University College London, UK*, [3] *Sub-Department of Astrophysics, University of Oxford, UK*, [4] *Max-Planck-Institut für Radioastronomie, Germany*, [5] *Joint ALMA Observatory, Chile*, [6] *Centro de Astrobiología (CSIC-INTA), Spain*, [7] *Instituto de Radioastronomía Milimétrica, Spain*

We present a 3 mm molecular line survey carried out towards the nucleus of the galaxy NGC 1068 using the IRAM 30 m telescope. The data, combined with time- and depth-dependent chemical models, allowed us to study the signatures of the cosmic rays, UV fields, and C-shocks in the surroundings of this Seyfert 2 active galactic nucleus (AGN). We establish a chemical differentiation between AGNs and starburst galaxies by comparing a complete inventory of species, and their abundances, in NGC 1068 with those obtained in M 82 and NGC 253. Future observations of ALMA would allow to study in detail how each species is affected by the different physical processes that can be found in galaxy nuclei at pc scales.

A Detailed Study of the Magnetic Field Properties of NGC 2024 FIR 5 with ALMA

Felipe Alves[1], Josep M. Girart[2], Shih-Ping Lai[3],Ramprasad Rao[4], Qizhou Zhang[5]
[1]*Argelander-Institut für Astronomie - German ARC Node*
[2]*Institut de Ciències de l'Espai (IEEC-CSIC)*
[3]*National Tsing Hua University*
[4]*Submillimeter Array/Academia Sinica*
[5]*Harvard-Smithsonian Center for Astrophysics*

The future capabilities of the Atacama Large Millimeter/submillimeter Array (ALMA) encourage astronomers to apply for ambitious projects where very high sensitivity is required. Full-Stokes parameter data will be provided by dual polarization receivers when the full capabilities observations begin, allowing for dust continuum and spectral line polarization observations. For first science, ideal targets should emit a strong mm/submm polarization flux and be located at short distances. In this project, I propose observations of the binary system NGC 2024 FIR 5, a nearby ($\sim$ 415 pc) low/intermediate-mass star-forming region where a strong dust continuum polarization flux was recently reported. ALMA will resolve the polarized emission of both components and show if the object gas motions are dynamically regulated by the magnetic field. In addition, hints on the complex evolutionary state of each object can be retrieved from their magnetic field morphology, outflow emission and chemical evolutionary tracers. Finally, a brief review on polarization campaigns running in parallel aims to show their relevance for preparing future ALMA polarization observations.

The giant bipolar jet from Sanduleak's star in LMC: from APEX to ALMA

R. Angeloni[1,2], D. M. Salter[1,3], L. Bizzocchi[4], F. Di Mille[5,6]
[1]*Departamento de Astronomía y Astrofísica, Pontificia Universidad Católica de Chile, Santiago, Chile*
[2]*Departamento de Ingeniería Eléctrica, Pontificia Universidad Católica de Chile, Santiago, Chile*
[3]*University of Maryland, Department of Astronomy, College Park, MD, USA*
[4]*Centro de Astronomia e Astrofísica da Universidade de Lisboa, Observatório Astronómico de Lisboa, Lisbon, Portugal*
[5]*Sydney Institute for Astronomy, The University of Sydney, Sydney, Australia*
[6]*Las Campanas Observatory, La Serena, Chile*

We recently discovered a remarkable, highly collimated, bipolar jet around Sanduleak's star, an intriguing object controversially classified as a symbiotic star. With a physical extent spanning more than 14 pc, this is one of the largest stellar jets ever discovered, and the first beyond the Milky Way to be spatially resolved. The observational evidence presents challenges to our current understanding of astrophysical jets. In this respect, regardless of origin, we believe that Sanduleak's bipolar outflow will be a crucial test-bed for future observations and modeling. We have been granted telescope time on HST/WFC3 and SOAR/SPARTAN to do follow-up high-spatial resolution imaging in the optical/NIR. Here, we present the details of our APEX/LABOCA and SABOCA observations to detect the continuum emission at 345 and 850 GHz and search for the presence of cold dust created by the central symbiotic source. In addition, the SHeFI APEX-1 and APEX-2 heterodyne receivers are offering stringent constraints on the molecular gas content by probing the 12CO (2-1) and (3-2) line emission along the optical jet axis. Our APEX observations are giving insight into the nature of the central source, helping to establish Sanduleak's jet as a promising source for future detailed studies with ALMA.

ALMA observations of non-thermal emission from colliding winds in close massive binaries

Anabella T. Araudo[1], Luis Felipe Rodríguez[1]
[1] *Centro de Radiostronomía y Astrofísica, Universidad Nacional Autónoma de Mexico, Morelia 58089, Mexico*

Colliding wind binaries are useful scenarios to study the properties of stellar winds, in particular those from massive stars. Up to now, radio observations at frequencies below 40-50 GHz allow to detect the wind collision region only if both stars are separated by a distance such that the collision region is located outside the opaque radio photospheres of the stars. With ALMA, it will be possible to observe in the continuum with high sensitivity up to frequencies ~ 370 GHz, where the radio photosphere is smaller than at lower frequencies, allowing to detect the thermal emission produced much closer to the stellar surface (resolving the binary) as well as the wind collision region. Then, ALMA will be able for the first time to study the millimeter (mm) and sub-mm emission in a regime of binary separations previously unexplored (periods shorter than about a year). In the present contribution we study close and massive binaries where at least one of the shocks produced by the winds collision is adiabatic and non-thermal emission is expected. We do not expect significant dust formation (that may confuse the mm and sub-mm emission) in these adiabatic shocks. The detection of synchrotron radiation produced closer to the stars is useful to estimate the value of the wind magnetic field, magnitude that is poorly known in massive stars. In addition to that, the production of clumps in the wind can be tested by the effect of them passing through the shocks.

The molecular gas content and the thermal radio emission from gravitationally lensed star forming galaxies revealed by the SPT, ATCA and ALMA

M. Aravena[1], and the SPT SMG collaboration
[1] *European Southern Observatory*

The South Pole Telescope (SPT) has recently unveiled a population of gravitationally lensed, highly magnified, dusty star-forming galaxies in a deep mm survey over 2500 deg^2 of sky. These correspond to the rarest and brightest submillimeter galaxies in the sky spanning a broad redshift range. We are conducting a systematic follow-up campaign with the Australia Telescope Compact Array (ATCA) to study the molecular gas content through observation of low-J CO emission in a sample of the SPT sources that have accurate CO-based spectroscopic redshifts and high-resolution continuum imaging from Atacama Large Millimeter/submillimeter Array (ALMA) follow-up. The ATCA observations of the CO line emission and radio continuum are crucial to estimate the total content of molecular gas and to investigate the physical conditions of the interstellar medium (ISM) through modeling of the CO ladder and FIR-to-radio spectral energy distribution. Here, we present preliminary results of this campaign, which include significant detections of CO and identification of free-free emission in star-forming galaxies at $z > 2 - 6$.

Studying Stellar Feedback and Accretion in Young Stellar Objects with ALMA

Héctor G. Arce[1], Diego Mardones[2], Adele Plunkett[1,2], Michael Dunham[1], Xuepeng Chen[3]
[1] *Yale University, USA*
[2] *Universidad de Chile, Chile*
[3] *Purple Mountain Observatory, China*

Energetic outflows and winds from young stars are among the most prominent signposts of star formation and may play an important role in the star formation process. Outflows and winds inject energy and momentum into their surroundings and have a considerable impact on the dynamics, distribution, and chemical composition of the gas in star-forming clouds. Molecular outflows also serve as fossil records of the mass outflow and accretion history of protostars. We discuss how millimeter and sub-millimeter telescopes are used to investigate the effects of outflows and winds on their surrounding environment. We present multi-line CARMA, SMA and ALMA Cycle 0 observations aimed at studying outflow-cloud interactions in star forming regions, the impact of outflows on dense cores, and the accretion history of protostars.

The ALMA Observation Support Tool: An Early Science Review

Adam Avison[1], Ian Heywood[2]
[1] *UK ALMA Regional Centre Node, Jodrell Bank Centre for Astrophysics, The University of Manchester, Oxford Road, Manchester, M13 9PL, UK*
[2] *Subdepartment of Astrophysics, University of Oxford, Denys-Wilkinson Building, Keble Road, Oxford, OX1 3RH, UK*

The ALMA Observation Support Tool (OST) is a web-based ALMA simulator aimed at the none interferometry expert user. Accessible from any standard web browser the OST is designed to allow full imaging simulation capability for any arbitrary ALMA observation whilst being as accessible as other ALMA online tools. The OST has been available since the ALMA Cycle 0 call for proposals announcement and has been extensively used by the international astronomy community in both ALMA Cycle 0 and Cycle 1 call for proposals. We present a synopsis of the OST itself, statistics on OST usage during ALMA Cycle 0 and Cycle 1 Call for Proposal periods (and beyond) and provide an outline for potential OST development in the future, from which we hope to encourage feedback from the ALMA community to guide this development.

Peering into the Hearts of the Most Luminous Local Galaxies: Using VLA Maps of mm-wave Radio Continuum to Probe the Central Regions of Local LIRGs and ULIRGs.

Loreto Barcos-Muñoz[1], Adam K. Leroy[2], Aaron S. Evans[1,2], Emmanuel Momjian[3], Eric Murphy[4], Lee Armus[5], James Condon[2], Sebastian Haan[5], Joseph M. Mazzarella[5], David S. Meier[3,6], Jürgen Ott[3], George C. Privon[1], Eva Schinnerer[7], Jason Surace[5], and Fabian Walter[7]

[1]*Department of Astronomy, University of Virginia, USA*, [2]*National Radio Astronomy Observatory, Charlottesville, USA*, [3]*National Radio Astronomy Observatory, USA*, [4]*Observatories of the Carnegie Institution for Science, USA*, [5]*Spitzer Science Center, California Institute of Technology, USA*, [6]*New Mexico Institute of Mining and Technology, USA*, [7]*Max Planck Institut für Astronomie, Germany*

Many of the most luminous galaxies in the local universe are distant, compact, heavily dust-embedded merger-induced starbursts - properties that make them difficult to study in detail. Radio continuum produced by star formation and AGN activity offers an unbiased view of the compact central sources in these galaxies. We present new, high-resolution, high frequency (29-36 GHz) radio continuum maps obtained with the recently upgraded Karl G. Jansky Very Large Array of 22 local luminous and ultraluminous infrared galaxies, highlighting 7 maps with particularly interesting substructure. Our high resolution (< 0.1"   50 pc at 100 Mpc) and sensitivity to all spatial scales allows us to make the best measurements to date of the extent and spectral energy distribution of the bright cores of these galaxies. We use these to estimate the true size of any nuclear starburst and constrain the nature of the central energy source. These radio continuum maps trace recent star formation and represent a matched-resolution complement to ongoing and future ALMA studies of the distribution of gas and dust in these most active local systems.

The Preponderance of Disks and the Brown Dwarf/Planetary Mass IMF in ρ Oph

Mary Barsony[1], Karl E. Haisch, Jr.[2], Ken Marsh[3], Alwyn Wootten[4]

[1]*SETI Institute*

[2]*Utah Valley University*

[3]*Cardiff University*

[4]*NRAO*

The lowest mass free-floating planetary mass object (PMO) known to date, at 2 Jupiter masses, lies in the nearby (d=125 pc), Southern star-forming region of ρ Oph (Marsh et al. 2010). More recently, we have discovered nearly 1000 candidate young substellar and planetary mass objects in this same cloud, potentially quadrupling the number of known members of this star-forming region (Barsony et al. 2012). Since 80% of these newly identified sources exhibit near-infrared excess emission indicative of the presence of disks, the opportunity now exists to study primordial disk properties across the substellar to planetary mass regime. Only ALMA, with its exquisite sensitivity to cold dust emission, where the bulk of the disk mass resides, can detect, let alone explore the properties of, this unprecedented source sample. For early science observations, we have selected a sub-sample of spectroscopically confirmed young brown dwarfs and planetary mass objects to: 1) detect their disks at submillimeter wavelengths for the first time; 2) to measure (or set stringent upper limits on) their disk masses; 3) to measure (or set upper limits to) their disk sizes. These early results will already have a major impact on our understanding of brown dwarf, PMO, and planetary system formation.

Antenna Surface Measurements Using Astronomical Sources

Samantha Kaj Blair[1], The Commissioning and Science Verification Team[1]
[1] *Joint ALMA Observatory*

The surface of an antenna must be accurate to a small fraction of the wavelength of the incoming signal in order to collect signals with high efficiency. For observations at sub-millimeter wavelengths it is critical to have extremely accurate means of measuring antenna surfaces and for monitoring their deformations under a range of conditions.
We have made measurements of the surfaces of the ALMA antennas using signals from astronomical sources, typically bright quasars. We employ the full interferometer array for this purpose, using some of the antennas to provide phase and amplitude reference signals while scanning the antennas under test in a raster pattern. Fourier inversion of the resulting measurement of the complex beam pattern yields a map of the errors in the wavefront at the aperture. We call this method "astro-holography" to distinguish it from holographic antenna measurement techniques using man-made transmitters.
The poster will present data showing that, under very good conditions, the repeatability in the measurements can approach the level of 1 micron rms. It will also demonstrate that the deformations in the surface due to gravity and thermal effects are easily detected.

Constraints on cosmological parameters using S-Z/X-Ray data from galaxy clusters.

A. Bonilla[1], V. Cárdenas[1], V. Motta[1]
[1] *Departamento de Física y Astronomía, Facultad de Ciencias, Universidad de Valparíso, Chile.*

Studies dedicated to restrict cosmological parameters is of primary importance to modern cosmology, because through these we can get a suitable model of the universe, leading to an understanding of its origin and evolution. Several observational tests favor of the so called concordance model (ΛCDM), which is the most accepted today. However, there are strong theoretical arguments to look for alternative models, and so it is neccesary to increase the number of independent tests. Here we present a new test using Sunyaev-Zeldovich/X-Ray (S-Z/X-Ray) data from which we can estimate distances to galaxy clusters, and from them, to constrain alternative cosmological models. In this paper we present preliminar results of a study using two galaxy cluster datasets ($De\ Filippis$ 2005 $and\ Bonamente$ 2006).

Breaking Cosmic Dawn - Observing Galaxies at $z \sim 7$ with ALMA

Maruša Bradač[1]
[1] *UC Davis*

To fully understand the role that reionization played in shaping today's galaxies, it is important to find and identify objects that form in the later stages of the epoch of reionization. These populations connect in a directly observable way to the galaxies we see today and knowledge of their star formation is needed to form a complete picture of galaxy evolution. The exceptional angular resolution and sensitivity of ALMA make it possible to probe the conditions of the neutral ISM in a starburst galaxy with a mass similar to that of the Milky Way at high redshift. Paired with magnification from best cosmic telescopes we can push this endeavours to redshifts close to reionization ($z \sim 6$ and beyond). In addition, highly magnified sources often reach magnifications > 10, which gives us access into sub-kpc regime and allow us to characterize the spatial distribution, and kinematics of the cold inter stellar medium in these extremely high redshift and not ultra luminous galaxies, something that would not be possible without the help of gravitational lensing.

In this talk I will present the ongoing efforts to observe highest redshift galaxies. In particular I will present first results from ongoing and future cluster surveeys (like SURF'S UP-Spitzer UltRaFaint SUrvey, a Spitzer Exploration Science Program where 550 hours have been devoted to observe best cosmic telescopes and study stellar populations in $z \sim 7$ sources) and how these will pair up with the future observations with ALMA.

How to find young massive cluster progenitors from the Milky Way to the local Universe

Eli Bressert[1], Jill Rathborne[1], Steven Longmore[2], Leonardo Testi[2], John Bally[3], Nate Bastian[4]
[1] *CSIRO Astronomy and Space Science, Epping, Sydney, Australia*
[2] *European Southern Observatory, Karl-Schwarzschild-Str. 2, 85748 Garching bei Munchen, Germany*
[3] *Center for Astrophysics and Space Astronomy, University of Colorado, UCB 389, Boulder, CO 80309*
[4] *Astrophysics Research Institute, Liverpool John Moores University, Twelve Quays House, Egerton Wharf, Birkenhead, CH41 1LD, UK*

The formation and early evolution of young massive clusters (YMCs) and their larger cousins, globular clusters, are largely unknown. By understanding their formation processes we can unlock key information about their natal environments in the present and early Universe.

In the Milky Way there is only one known starless YMC precursor (G0.025+0.016; Longmore et al. 2012) that has been well studied from infrared to radio wavelengths for spatial and kinetic information. With recent ALMA observations (PI: J. Rathborne) we have just begun analysing the complex structures in the object, which is providing us with important insight on YMC formation. Unfortunately, G0.25+0.016 is most likely one of very few YMC precursors in the Milky Way.

With ALMA we can expand our frontier to study extragalactic YMC precursors as predicted in Bressert et al. (2012) that were once too dim and small to observe. Deriving from the G0.025+0.016 ALMA data we provide a prescription on how to find these extragalactic sources with future ALMA observations. In turn, we will acquire the necessary tools to better understand massive stellar cluster origins.

ALMA Science Verification: TW Hya & HD 163296

The Commissioning and Science Verification Team[1,2]
[1]*Joint ALMA Observatory*
[2]*ALMA Regional Centres*

We present an overview of ALMA Science Verification (SV) on the two protoplanetary disks TW Hya and HD 163296. SV is the process by which we demonstrate that ALMA is capable of producing data of the quality required for scientific analysis and by which we fully test all observing modes expected to be available during Early Science. The study of protoplanetary disks is one of the main science goals expected to be exploited by external ALMA users, and there have already been a large number of external users wishing to obtain data on this type of object. The TW Hya SV datasets, in Bands 3, 6 and 7, and the HD 163296 datasets, in Bands 6 and 7, were used to test end-to-end ALMA observations of disks at high spectral resolution, mixing continuum and line measurements in a number of setups that we predict will be popular among external users.

In this presentation we review the SV datasets that were obtained and released, the SV process and results, and as far as possible will aim not to conflict with any individual science presentations that use the same SV data.

ALMA Science Verification: Orion-KL spectral survey

The Commissioning and Science Verification Team[1,2]
[1]*Joint ALMA Observatory*
[2]*ALMA Regional Centres*

We present an overview of ALMA Science Verification (SV) on Orion-KL in Band 6. The Orion KL region is known to have a large diversity of molecular emission and clear chemical differentiation between N and O bearing species. SV is the process by which we demonstrate that ALMA is capable of producing data of the quality required for scientific analysis and by which we fully test all observing modes expected to be available during Early Science. The SV observations of Orion-KL were carried out at Band 6 as a high resolution spectral survey. We confirm that the spatial distribution of the averaged continuum emission around 231 GHz and the methanol J=8(-1,8)-7(0,7) emission line at 229.76 GHz are in agreement with the previous observations of Friedel & Snyder (2008). Given the complexity of the source, many other molecules are also detected, each having a very different spatial flux distribution.

In this presentation we review the SV datasets that were obtained and released, the SV process and results, and as far as possible will aim not to conflict with any individual science presentations that use the same SV data.

ALMA Science Verification: SgrA* recombination lines in Bands 3 and 6

The Commissioning and Science Verification Team[1,2]
[1]*Joint ALMA Observatory*
[2]*ALMA Regional Centres*

We present an overview of ALMA Science Verification (SV) on SgrA*, the Galactic centre, in Bands 3 and 6. SV is the process by which we demonstrate that ALMA is capable of producing data of the quality required for scientific analysis and by which we fully test all observing modes expected to be available during Early Science. The SV observations of SgrA* were aimed at mapping the continuum and hydrogen recombination lines in the mini-spiral structure within a parsec of the Galactic center, with a single pointing in Band 3, and a 7-point mosaic in Band 6, covering a 1-arcmin region of the target. H30alpha emission at 231.9 GHz (Band 6) and H39alpha emission at 106.73 GHz (Band 3) were imaged at arcsec resolution. Several molecular lines are seen in absorption toward SgrA* throughout the spectrum.

In this presentation we review the SV datasets that were obtained and released, the SV process and results, and as far as possible will aim not to conflict with any individual science presentations that use the same SV data.

ALMA Science Verification: NGC 3256

The Commissioning and Science Verification Team[1,2]
[1]*Joint ALMA Observatory*
[2]*ALMA Regional Centres*

The luminous infrared galaxy NGC 3256, which is in the later stages of a merger of two gas-rich progenitors and hosts an extreme central starburst, is the brightest galaxy within $\sim$40 Mpc. We present an overview of ALMA Science Verification (SV) data on NGC 3256 in Band 3, which includes the CO(1-0) line. SV is the process by which we demonstrate that ALMA is capable of producing data of the quality required for scientific analysis and by which we fully test all observing modes expected to be available during Early Science. The NGC 3256 observations were carried out using a low spectral resolution setup (80 km/s per channel) and the angular resolution is approximately $6.0''$. We confirm that the spatial distribution of the ALMA CO(1-0) data is consistent with previous SMA CO(2-1) data. Also, we are able to detect the high velocity gas in the centre of the galaxy that was previously identified as molecular outflow in the CO(2-1) line.

In this presentation we review the SV datasets that were obtained and released, the SV process and results, and as far as possible will aim not to conflict with any individual science presentations that use the same SV data.

ALMA Science Verification: Centaurus A (NGC 5128)

The Commissioning and Science Verification Team[1,2]
[1] *Joint ALMA Observatory*
[2] *ALMA Regional Centres*

Centaurus A (NGC 5128) is the closest radio powerful galaxy and giant elliptical, at only 3.8 Mpc. We present an overview of ALMA Science Verification (SV) on Centaurus A in Band 6, which includes the CO(2-1) line. SV is the process by which we demonstrate that ALMA is capable of producing data of the quality required for scientific analysis and by which we fully test all observing modes expected to be available during Early Science. The observed Centaurus A data is a 46 point mosaic, covering the inner 3 arcminnutes (3 kpc) along the gaseous and dusty disk of the galaxy, with a resolution of $2.9'' \times 0.8''$ ($1''$ is 18 pc) and a sensitivity of 2.5 mJy/beam. We confirm that the ALMA data has similar distribution to previous CO maps, with a circumnuclear rotating disk in the inner 400 pc and more extended structure further from the center. Continuum emission is also detected and found to be unresolved, and CO(2-1) absorption features are detected towards it.

In this presentation we review the SV datasets that were obtained and released, the SV process and results, and as far as possible will aim not to conflict with any individual science presentations that use the same SV data.

ALMA Science Verification: Antennae galaxies (NGC 4038/9)

The Commissioning and Science Verification Team[1,2]
[1] *Joint ALMA Observatory*
[2] *ALMA Regional Centres*

The Antennae (NGC 4038/9) is one of the nearest (22 Mpc) colliding galaxy pairs. Consisting of two spiral galaxies that started to interact only a few hundred million years ago, it is one of the youngest examples of a major galaxy merger. We present an overview of ALMA Science Verification (SV) on the Antennae galaxies in Bands 6 and 7, which includes the CO(2-1) and CO(3-2) lines. SV is the process by which we demonstrate that ALMA is capable of producing data of the quality required for scientific analysis and by which we fully test all observing modes expected to be available during Early Science. The SV data on the Antennae galaxies were taken as two mosaics, one northern and one southern, with up to 27 pointings per mosaic. Molecular emission is detected throughout the system and is particularly bright in the 'interaction region' between the two nuclei. We confirm that the spatial distribution of the ALMA CO data is consistent with previous CO maps.

In this presentation we review the SV datasets that were obtained and released, the SV process and results, and as far as possible will aim not to conflict with any individual science presentations that use the same SV data.

Dissecting disks around B-type (proto)stars

R. Cesaroni[1], H. Zinnecker[2], M.T. Beltrán[1], S. Etoka[3], D. Galli[1], C. Hummel[4], M.S.N. Kumar[5], L. Moscadelli12, T. Preibisch[6], R. Thorsten[6], A. Sanchez-Monge[2], T. Stanke[4], F. Van der Tak[7], S. Vig[8], C.M. Walmsley[1], K.-S. Wang[9]
[1] *INAF, Osservatorio Astrofisico di Arcetri, Firenze, Italy*
[2] *SOFIA Science Center, NASA Ames Research Center, U.S.A.*
[3] *Jodrell Bank Centre for Astrophysics, Univ. of Manchester, U.K.*
[4] *ESO, Garching bei München, Germany*
[5] *Centro de Astrofísica da Universidade do Porto, Portugal*
[6] *Universitäts-Sternwarte München, Germany*
[7] *SRON Netherlands Institute for Space Research, Groningen, The Netherlands*
[8] *Department of Earth and Space Science, Indian Institute of Space Science and Technology, Thiruvananthapuram, India*
[9] *Leiden Observatory, The Netherlands*

Recent theoretical models indicate that OB-type stars could form through disk-mediated accretion, like their low mass counterparts. However, on the observational side, circumstellar disks appear still elusive, especially around the most massive (proto)stars. As for early B-type (proto)stars, an ever growing number of disk candidates has been proposed, but only very few of these present clear signatures, such as Keplerian or sub-Keplerian rotation. The advent of ALMA provides us with the necessary sensitivity and angular resolution to assess the existence of such disks and possibly establish their rotation curves. With this in mind, we have performed ALMA observations with the highest possible resolution (∼0.4") at 350 GHz to search for circumstellar disks in a couple of presumably massive young stellar objects with luminosities of $\sim 10^4\ L_\odot$ and associated with bipolar nebulosities suggestive of the presence of disk/outflow systems. By observing simultaneously core and jet tracers, we could reveal molecular cores with velocity gradients perpendicular to the corresponding jets. In both targets (G35.2N, G35.03), the core structure appears resolved and the corresponding position-velocity plot is suggestive of (sub-)Keplerian rotation about a massive star. The results will be illustrated and discussed with the help of ancillary data at different wavelengths. Disk fragmentation will also be discussed, but can only be tackled with higher angular resolution ALMA observations.

Observations of molecular lines in protoplanetary surrounding low-mass stars

Edwige Chapillon[1]
[1] *Academia Sinica, Institute of Astronomy and Astrophysics, Taiwan*

Understanding the structure and evolution of disks surrounding young low-mass stars is one of the key issues to study the process of planet formation. Nevertheless the overall properties of those disks are not yet well constrained by observations. Several other molecules than CO and its isotopologues have been detected in the outer part of the disks in the millimeter domain : HCO^+, $H^{13}CO^+$, DCO^+, H_2CO, H_2O, CS, C_2H, N_2H^+, HCN, HNC, CN, DCN, and very recently HC_3N. These molecular tracers bring some constraints on the disk physical structure since they sample different physical conditions.
In this talk I will present recent results obtained thanks to molecular line observations, and confront them to models of proto-planetary disks, in particular to the the layered structure that is predictied by all chemical models so far.

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

S.Guilloteau[1], A.Dutrey[1], V.Wakelam[1], F.Hersant[1], D.Semenov[2], E.Chapillon[3], T.Henning[2] & V.Piétu[4]

[1] *Laboratoire d'Astrophysique de Bordeaux, France*, [2] *Max-Planck-Institut für Astronomie, Heidelberg, Germany*, [3] *Academia Sinica, Institute of Astronomy and Astrophysics, Taipei, Taiwan*, [4] *IRAM, Grenoble, France*

Turbulence is thought to be a key driver of the evolution of proto-planetary disks, regulating the mass accretion process, the transport of angular momentum, and the growth of dust particles. Turbulent motions can be constrained by measuring the non-thermal broadening of line emission from heavy molecules. We use the IRAM Plateau de Bure interferometer to study CS emission in the disk of DM Tau. High spatial ($1.4 \times 1''$) and spectral resolution (0.126 km s^{-1}) CS(3-2) images provide constraints on the molecule distribution and velocity structure of the disk. A low sensitivity CS(5-4) image is used in conjunction to constrain the excitation conditions. We analyze the data in terms of two parametric disk models, and compare with detailed time-dependent chemical simulations. The measured intrinsic linewidth derived from the CS(3-2) data is much larger than expected from pure thermal broadening. The magnitude of the derived non thermal component depends very weakly on assumptions about the location of the CS molecules with respect to the disk plane. Our results suggest turbulence with a Mach number around 0.5 in the molecular layer. Geometrical constraints indicate this layer is located between 0.5 - 1.5 scale heights, somewhat lower than predicted by chemical models.

A close look at low-mass star forming regions: first ALMA results from science verification (SV) data

Edwige Chapillon[1], Satoko Takahashi[1], Naomi Hirano[1], Sheng-Yuan Liu[1], and Taiwan ARC node members[1], Eiji Akiyama[2], Bill Dent[3], Daniel Espada[2], Antonio Hales[3], Itziar de Gregorio[3], Pamela Klaassen[4], Geoff Mathews[4], Attila Juhasz[4], Mark Rawling[3] and Leonardo Testi[5]

[1] *ASIAA, Taiwan , Taipei*, [2] *NAOJ, Tokyo, Japan*, [3] *JAO, Santiago, Chile*, [4] *Leiden Observatory, the Netherland*, [5] *ESO, Garching, Germany*, [6] *INAF-Osservatorio Astrofisico di Arcetri, Firenze, Italy*

We present new insight on star formation using ALMA SV observation comprising the low mass star forming region IRAS 16293-2422 and the protoplanetary disks HD 163296.

The band 9 SV data of IRAS 16293-2422, a well-studied class 0 system, are very rich in molecular lines. Toward source B, most of the dense gas tracers show a shell-like emission feature with deep absorption toward the center of the continuum emission, of emission and absorption features supporting the dense gas is infalling (Pineda et al. 2012, Zapata et al. in prep.). infalling gas motion hypothesis (Pineda et al. 2012, Zapata et al. in prep.). A velocity gradient ($\sim$10 km^{-1}) along the NE-SW direction (across 1.5″/240 AU) was detected around the multiple source A, with absorption at the continuum peak. We will discuss the spatial distributions, physical properties, and kinematics of the dense gas around source A and B.

The Herbig Ae star HD 163296 is surrounded by a protoplanetary disk in Keplerian rotation. This disk displays bright CO lines. We used the high resolution SV data to study in details the disk's kinematics and the (radial and vertical) structure, using a simple power-law parametric model and a radiative transfer code dedicated to disks. We focus our study on the (J=2-1) lines of the three most abundant isotopologues of CO observed in the Band 6 data.

NGC 4654, a Proxy for H_2 Formation from HI by the ICM Pressure?

Eun Jung Chung[1], Sungeun Kim[1], Aeree Chung[2]
[1] *Dept. of Astronomy and Space Science, Sejong University*
[2] *Dept. of Astronomy, Yonsei University*

NGC 4654 is located at 3.3° northeast of M87, the center of the Virgo cluster. This galaxy is found with a long one-sided HI tail and HI compression on the opposite side, which is good evidence for ram pressure stripping. Whereas, ^{12}CO($J = 1 \rightarrow 0$) does not show any of such features as found in atomic hydrogen gas but it is well bound within the inner stellar disk. It is however asymmetric in the way that it is more extended to the same side of the HI compression. A number of Hα knots are preferentially found in the same side of the disk, implying that active star formation are taking place along the CO extent. Here we propose that more molecular gas can form out of atomic gas by the external pressure, which can locally enhance the star formation activity.

Molecular Gas Properties along the Ram Pressure Time Sequence

Eun Jung Chung[1], Aeree Chung[2], Sungeun Kim[1]
[1] *Dept. of Astronomy and Space Science, Sejong University*
[2] *Dept. of Astronomy, Yonsei University*

The ram pressure is known as one of the most efficient mechanisms to remove the interstellar medium of a galaxy in the clusters of galaxies. As galaxies get stripped by the ICM pressure, their star formation rate would also change. We have selected thirteen Virgo spirals at a range of ram pressure stripping stages in order to probe how their molecular gas properties and star formation activities change with the ICM pressure. The gas properties, star formation activity, and gas depletion time are investigated along the time from the ram pressure peak.

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Dynamical black-hole mass measurements with molecular gas

Timothy A. Davis[1], Martin Bureau[2], Michele Cappellari[2], Marc Sarzi[3], Leo Blitz[4]
[1] *European Southern Observatory, Karl-Schwarzschild-Str. 2, 85748, Garching-bei-München, DE*
[2] *Denys Wilkinson Building, Keble Road, Oxford, OX1 3RH, UK*
[3] *Centre for Astrophysics Research, University of Hertfordshire, Hatfield, Herts AL1 9AB, UK*
[4] *Department of Astronomy, University of California, Berkeley, CA 94720, USA*

The masses of the supermassive black-holes found at the centre of giant galaxies are correlated with a multitude of galaxy properties, implying galaxies and black-holes may co-evolve in a self-regulated manner. The physics behind this co-evolution is the subject of much speculation, but the number of reliably measured black-hole masses is small and the number of methods for measuring them limited, holding back progress in this area. I will show for the first time that black-hole masses can be measured accurately by using molecular gas as a kinematic tracer, by presenting high-resolution CARMA observations, where we were able to resolve the sphere-of-influence of the black-hole in the fast-rotating ETG NGC4526. Modelling the rotation of the molecular gas reveals the presence of a central dark object of mass $(4.5 \pm 1.4) \times 10^8$ $M_\odot$, consistent with a black-hole. Molecular gas observations of this type should become routine in the next few years, thanks to the unprecedented resolution and sensitivity of ALMA. I will show that using this technique, one should be able to measure black-hole masses in many hundreds of galaxies of differing masses and morphological types with ALMA, reducing systematic uncertainties and revolutionising studies of the co-evolution of black-holes and galaxies.

Studies with ALMA of warm molecular outflows around T Tauri stars: critical tests of MHD launching

Catherine Dougados[1,2], Sylvie Cabrit[3]
[1] *LFCA, Depart. de Astronomia, Universidad de Chile*, [2] *Institut de Planetologie et d'Astrophysique de Grenoble (IPAG)*, [3] *LERMA Observatoire de Paris*

I will discuss in this contribution two preparatory studies to test with ALMA the origin of jets from T Tauri stars and their impact on the physics of the inner protoplanetary disc. Supersonic jets are one of the most spectacular manifestation of the formation of a young star. The exact origin of these jets and the role they play in solving the angular momentum problem in young stars are still major open issues in star formation.
One of the strongest observational support for MHD disc ejection comes from the tentative detection of rotation signatures in T Tauri atomic jets (Bacciotti et al. 2002; Ferreira, Dougados, Cabrit 2006). However, other processes than rotation can account for the observed transverse velocity shifts (e.g. jet precession). In particular, we demonstrated in one system that the disc rotation sense determined from millimetric studies is opposite to the jet rotation sense determined in the optical (Cabrit et al. 2006). We will discuss a critical test that ALMA could provide of the rotation interpretation.
ALMA will also provide critical constraints to test the origin of the warm ($T \simeq 2000$ K) molecular outflow components recently detected in H_2 lines within 100 AU of T Tauri and Herbig Ae/Be stars, both in the near-infrared and in the FUV domains (e.g. Herczeg et al. 2002, 2006; Beck et a. 2007). The presence of outflowing H_2 might be an indication that MHD ejection is operating out to larger radii than suggested by atomic jet studies. We recently analyzed the low velocity H_2 outflow associated with the jet driving T Tauri star DG Tauri, using observations conducted with SINFONI/VLT (Agra-Amboage et al. submitted). The observed properties of the H_2 flow in DG Tau are in good agreement with predictions for both a magneto-centrifugal disk wind ejected from 5-10 AU and heated by ambipolar diffusion (Panoglou et al. 2012) and a photo-evaporative flow from the irradiated disc surface launched beyond 10 AU. We will discuss how ALMA, with its very high spectral resolution (2 orders of magnitude improvment over the near-IR studies), will potentially allow to discriminate between these two models which have distinct implications for the disc structure, in particular the degree of magnetisation, in the terrestrial planet formation zone.

Detection and Characterization of Candidate First Hydrostatic Cores

Michael M. Dunham[1], Héctor G. Arce[1], Tyler L. Bourke[2], Xuepeng Chen[3], Manuel Fernandez[4], Diego Mardones[5], Jaime Pineda[6], & Schott Schnee[7]
[1] *Yale University*, [2] *CfA*, [3] *Purple Mountain Observatory*, [4] *Illinois*, [5] *U. de Chile*, [6] *ESO*, [7] *NRAO*

The first hydrostatic core is a short-lived object that exists intermediate between the pre- and protostellar stages of star formation that was predicted over 40 years ago but has not yet been reliably confirmed by observations. Over the past two years several candidate first hydrostatic cores have been detected through various methods. While at least some are likely to be extremely low luminosity protostars, one or more of these candidates may in fact be true first cores. We propose to present a poster on the detection and characterization of these objects. We will summarize all known candidates and the methods by which they were identified. We will also present new SMA and CARMA data aimed at determining the propeties of both the outflowing gas and the dense gas in the cores themselves, with the ultimate goal of revealing the true evolutionary status of these intriguing new objects. Finally, we will discuss near-term future prospects for identifying and characterizing first cores with ALMA early- and full-science operations.

Obscured star-formation revealed by Herschel in HiZELS Hα emitters at z $= 1.47$ – targets for a synergy between ALMA and VLT.

Edo Ibar[1,2], David Sobral[3] & the HerMES, PEP and HiZELS collaborations

[1] *UK Astronomy Technology Centre, Royal Observatory, Edinburgh, UK* [2] *Universidad Católica de Chile, Chile*, [3] *Leiden Observatory, The Netherlands*

We describe the far-infrared properties of a sample of 443 Hα-selected star-forming galaxies in the COSMOS and UDS fields detected by the HiZELS imaging survey. Sources are identified using narrow-band filters in combination with broad-band photometry to select Hα emitters at $z = 1.47$. To describe their properties, we use a stacking approach in mid-IR (*Spitzer*), far-IR (*Herschel*) and mm-wave (AzTEC) images to measure their typical star-formation rates (SFRs). We find that HiZELS galaxies with observed Hα luminosities of $\approx 10^{41.5-42.5}$ erg s^{-1} have bolometric far-IR luminosities of $L(8-1000\,\mu\mathrm{m}) \approx 10^{11.48^{+0.04}_{-0.05}}$ L$_{\odot}$. Perhaps surprisingly, there is only a mild correlation between far-IR luminosity and observed $L(\mathrm{H}\alpha)$. For this sample, we find a strong dependency of far-IR luminosity on stellar mass, where low-mass galaxies (M$_{\star} \sim 10^{9.7}$ M$_{\odot}$) tend to have $\sim 5\times$ lower $L(8-1000\,\mu\mathrm{m})$ than more massive galaxies (M$_{\star} \sim 10^{10.4}$ M$_{\odot}$) – assuming a Salpeter IMF and a TP-AGB component. Variations up to $\sim 1.2\,\mathrm{mag}$ are also seen for Hα extinction on the same range of stellar masses. The far-IR data suggest the existence of a heavily obscured star-forming component, which becomes difficult to observe in optical studies, especially at M$_{\star} > 10^{10}\mathrm{M}_{\odot}$. At low stellar masses, we find hints for a deviation of the HiZELS Hα emitters from the so-called 'main-sequence' for star-forming galaxies – an effect produced by the increasing importance of the Hα emission for tracing the unobscured SFR at low stellar masses. This work suggests that obscured star formation is intimately linked to the assembly of stellar mass, with deeper potential wells in massive galaxies providing dense, heavily obscured environments in which stars can rapidly form. *High-z HiZELS galaxies are key targets to describe the resolved SFR activity using optical and far-IR tracers – a novel synergy between ALMA and VLT.*

Debris disks observations with ALMA - First science and future perspectives

Steve Ertel[1], Jean-Charles Augereau[1], Alexander V. Krivov[2], Sebastian Wolf[3]

[1] *Institute of Planetology and Astrophysics Grenoble, France*, [2] *Astrophysical Institute and University Observatory, Friedrich Schiller Universität Jena, Germany*, [3] *Institute of Theoretical Physics and Astrophysics, Christian-Albrechts-Universität zu Kiel, Germany*

Debris disks are faint dust disks around main sequence stars. The presence, architecture, and evolution of these disks are thought to be closely connected to the properties and evolution of underlying planetary systems. Spatially resolved observations are es hard as they are critical to constrain these properties. ALMA represents a huge step forward due to its high angular resolution in the (sub-)millimeter. However, the relatively large angular extent of the nearby debris disks and their intrinsic faintness represent a major challenge to ALMA's sensitivity. Thus, ALMA observations of debris disks must be particularly well planned and optimized for the targeted system. If this is done properly, even large, efficient surveys with ALMA are possible.

I will discuss different strategies for debris disk observations with ALMA on the example of several cycle 0 and cycle 1 projects. I will complement this discussion by a preparatory, theoretical work on the observability of debris disks with ALMA in the context of planet-disk interaction. Finally, I will present the case of the cold debris disks detected by our Herschel Open Time Key Project DUNES. Here, ALMA is the only instrument for the next 10 years that allows one a mayor observational breakthrough.

Direct Detection of Asteroid Belts in Evolved Planetary Systems

Jay Farihi[1]
[1] *University of Cambridge*

There are now nearly 30 known examples of cool white dwarf stars orbited by rocky debris from tidally-destroyed minor planets. Because this warm debris orbits within 1 solar radius, the parent body must have originated in a more distant region populated by a substantial number and mass of remnant planetary bodies. We are pursuing ALMA observations to identify the orbital regions from which the parent bodies originate, by detecting and spatially-resolving cold dust from within this remnant planetesimal belt. The primary science goal is to distinguish between Main Belt and Kuiper Belt analogs, although the chemistry observed to date favors formation interior to a snow line. Additionally, we hope to obtain the first image of planetary debris around a stellar remnant, and provide insight into the fate of planetary systems at A- and F-type stars.
Critically and uniquely in white dwarfs, the bulk chemical compositions of the destroyed parent bodies can be determined via spectroscopy of the metal-polluted stellar atmospheres, and the ALMA observations will identify the formation region associated with this chemistry. With these data we will possess a nearly complete picture of rocky (and perhaps icy) minor planets around other stars; both where they formed and their bulk composition. Only white dwarfs offer this opportunity and ALMA observations represent an ideal way to highlight this scientific potential. We will present the first results from our Cycle 0 program and discuss short- and long-term future science aims, including how ALMA complements the upcoming generation of Extremely Large Telescopes.

Weak Lensing and Optical Analysis of the SARCS Lens Candidates

Gaël FOËX[1]
[1] *Departamento de Física y Astronomía, Universidad de Valparaíso, Valparaíso, Chile*

More et al. (2012) have compiled a sample of 127 possible group-scale lenses detected on the Canada-France-HawaiiTelescope Legacy Survey, the SARCS sample. It covers a large range in redshifts ($z \in [0.2 - 1.2]$), and represents a great opportunity to investigate in details the properties of the intermediate-mass regime of the matter spectrum that is hardly reached by X-ray or SZ observations. I present here the weak lensing analysis of the SARCS sample that consists in a fit of the observed shear profiles by the Singular Isothermal Sphere. We obtain a clear detection for 91 objects, with velocity dispersions ranging in $\sigma_{SIS} \sim 350 - 950\,\mathrm{km.s^{-1}}$, i.e. groups and poor clusters of galaxies. From the catalogs of the bright red galaxies, we estimate for each SARCS candidate their optical richness and luminosity, with typical values of $N_{0.5Mpc} \sim 5 - 15$ galaxies and $L_{0.5Mpc} \sim 0.5 - 1.5 \times 10^{12}\mathrm{L}_\odot$ (i-band, corrected from passive evolution) corresponding again to groups and poor clusters. We also compute luminosity maps to study the morphology of the groups. For the whole sample, we obtain $\sim 24\%$ of false detections or galaxy-scale objects (i.e. no clear over-density in the map), $\sim 30\%$ of regular groups, $\sim 32\%$ of groups with elongated and elliptical luminosity maps, and finally $\sim 14\%$ of multimodal groups. It appears that a large fraction of groups present a complicated light distribution suggesting that these objects are dynamically young structures. We also combine the weak lensing and optical analysis to draw a sample of 80 most secure groups candidates, from which we study the optical scaling relations. From the mass-richness relation, we do not observe any departure from the simplest theoretical prediction $M \propto N$. The scaling with the optical luminosity reveals on the other hand a non-constant mass-to-light ratio, with a significant increase from the lowest mass objects to regular groups, while the M/L value remains roughly constant up to rich galaxy clusters.

High-Sensitivity Observations of the Protoplanetary Disk around HD 142527 in ^{13}CO(3–2)

M. Fukagawa[1], N. Ohashi[2], M. Momose[3], Y. Kitamura[4], E. Akiyama[2], T. Tsukagoshi[3], Y. Aso[5], T. Takeuchi[6], H. Kobayashi[7], T. Muto[8], M. Honda[9], H. Fujiwara[2], H. Shibai[1]
[1]*Osaka University*, [2]*NAOJ*, [3]*Ibaraki University*, [4]*ISAS/JAXA*, [5]*The University of Tokyo*, [6]*Tokyo Institute of Technology*, [7]*Nagoya University*, [8]*Kogakuin University*, [9]*Kanagawa University*

Observations of protoplanetary disks are central to understand realistic initial conditions of planet building as well as to obtain valuable insights into young forming planets. The protoplanetary disk around the Herbig Fe star, HD 142527, is one of the best and unique sites to investigate disk-planet interaction and disk clearing mechanism in ALMA Early Science. As has been known by our previous studies in near-infrared and submillimeter, the disk has a large gap extending out to about 1 arcsec from the star, and it shows a strong non-axisymmetry including the eccentric gap, arm-like structures, and the dust density enhancement in the northern area. In Cycle 0, we have been observing HD 142527 in the lines of ^{13}CO(3–2) and C^{18}O(3–2) aiming to reveal the asymmetric structure in gas and dust, measure the gas kinematics, and estimate the dust-to-gas ratio even inside of the gap. If our observations are performed as planned, they will provide the sensitivity approximately 50 times greater than what was achieved with SMA. We will report the early results of our sensitive mapping for the protoplanetary disk of HD 142527.

PdBI observations of far infra-red emission lines in high redshift quasars

Simona Gallerani[1]
[1]*Scuola Normale Superiore di Pisa*

We present Plateau de Bure Interferometer (PdBI) observations of far infra-red emission lines in BRI 0952-0115 (B0952), a lensed QSO at z=4.4 powered by a super-massive black hole ($M_{\rm BH} = 2 \times 10^9 M_\odot$). In this source, the resolved map of the [CII] emission at 158 μm allows us to reveal the presence of a companion galaxy, located at ~ 10 kpc from the QSO, undetected in optical observations (Gallerani et al. 2012).
From the CO(5-4) emission line properties we infer a stellar mass $M_* < 2.2 \times 10^{10} M_\odot$. This value is significantly smaller than the one found in local galaxies hosting black holes with similar masses ($M_* \sim 10^{12} M_\odot$), suggesting that the black hole accretion process is more efficient at early epochs.
The detection of the [NII] emission at 205 μm allows us to measure the gas metallicity in B0952 which results to be consistent with solar, implying that the chemical evolution has progressed very rapidly in this system. In particular, the morphology of the [NII] emission is also suggestive of a SN/QSO-driven outflow.
We also present PdBI observations of the [CII] emission line in SDSSJ1148+5251 (S1148), one of the most distant QSO known, at z=6.4.
We detect broad wings in the [CII] emission line, indicative of gas which is outflowing from the host galaxy (Maiolino et al. 2012). In particular, the extent of the wings, and the size of the [CII] emitting region associated to them, are indicative of a QSO-driven massive outflow with the highest outflow rate ever found ($\dot{\rm M} > 3500$ M$_\odot$ yr^{-1}).
Our observations underline the importance of millimeter observations of high-z star-forming galaxies for constraining the properties of their ISM, and for studying processes related to galaxy formation, as galaxy merging and SN/QSO feedback.

ALMA and VLA observations of recombination lines and continuum toward the Becklin-Neugebauer object in Orion

Roberto Galván-Madrid[1], Ciriaco Goddi[1,2], Luis F. Rodríguez[3,4]
[1] *European Southern Observatory, Karl-Schwarzschild-Str. 2, 85748 Garching, Germany.*
[2] *Joint Institute for VLBI in Europe, Postbus 2, 7990 AA Dwingeloo, The Netherlands.*
[3] *Centro de Radioastronomía y Astrofísica, Universidad Nacional Autónoma de México, Morelia 58090, Mexico.*
[4] *Astronomy Department, Faculty of Science, King Abdulaziz University, P.O. Box 80203, Jeddah 21589, Saudi Arabia.*

Compared to their centimeter-wavelength counterparts, millimeter recombination lines (RLs) are intrinsically brighter and are free of pressure broadening. We report observations of RLs ($H30\alpha$ at 231.9 GHz, $H53\alpha$ at 42.9 GHz) and the millimeter and centimeter continuum toward the Becklin-Neugebauer (BN) object in Orion, obtained from the Atacama Large Millimeter/submillimeter Array (ALMA) Science Verification archive and the Very Large Array (VLA). The RL emission appears to be arising from the slowly-moving, dense ($N_e = 8.4 \times 10^6$ cm^{-3}) base of the ionized envelope around BN. This ionized gas has a relatively low electron temperature ($T_e < 4900$ K) and small ($<< 10$ km s^{-1}) bulk motions. Comparing our continuum measurements with previous (non)detections, it is possible that BN has large flux variations in the millimeter. However, dedicated observations with a uniform setup are needed to confirm this. From the $H30\alpha$ line, the central line-of-sight LSR velocity of BN is 26.3 km s^{-1}.

[CII] as a Star Formation Rate Tracer in the ALMA Era

Rodrigo Herrera-Camus[1], Alberto Bolatto[1], Mark Wolfire[1], KINGFISH Team
[1] *University of Maryland, College Park, MD 20742, USA*

The [CII] 158μm line is a major coolant for the diffuse interstellar gas and has a great potential to be used as a star formation rate tracer. Thanks to ALMA, the [CII] 158μm line will be detected in normal, star forming galaxies in the redshift range $1 < z < 3$. Using a sample of 40 nearby galaxies observed by *Herschel* as part of the KINGFISH project, we analyze how reliable is to measure the star formation rate from the [CII] 158μm line. We present correlations of [CII] 158μm with recently published recipes for star formation rates based on 24μm, Hα and FUV emission. We find a strong, linear correlation between [CII] 158μm luminosity surface density and star formation rate surface density for $\Sigma_{[CII]} \geq 3 \times 10^{38}$ [erg s^{-1} kpc^{-2}], corresponding to $\Sigma_{SFR} \geq 2 \times 10^{-3}$ [M$_\odot$ yr^{-1} kpc^{-2}]. We test the correlation using a simple model based on the *Starburst99* code to connect the star formation rate of a stellar population to the [CII] 158μm emission. We finally discussed the caveats related to using this calibration to measure star formation rates in high-z galaxies observed with ALMA.

Maps of Massive Clumps in the Early Stage of Cluster Formation

A. Higuchi[1], Y. Kurono[2], M. Saito[1], T. Naoi[2], R. Kawabe[1]
[1] *Joint ALMA Observatory*
[2] *National Astronomical Observatory of Japan*

We present maps of 7 young massive clumps within 5 target objects in the CO (J=1–0) line emission. We have selected these clumps, which are not associated with a cluster, at distances from 0.7 to 2.1 kpc and observed with the Nobeyama 45m telescope. We identified clumps with radii of 0.5–1.7 pc, masses of 470–4200 $M_{\odot}$, and velocity widths in FWHM of 1.4–3.3 $\mathrm{km\,s^{-1}}$, all of which are similar to those of the cluster-forming clumps. All of the clumps are found to be approximately in virial equilibrium, suggesting they have potential to form a cluster including massive stars. In our target objects, three of them are associated with H II regions (“CWHRs" from Clump with H II Region), and the others are without H II regions (CWOHRs). The CO clumps can be classified into two, namely one with filamentary or shell-like structure (CWHRs), the other being spherical (CWOHRs). Two clumps, which are not associated with H II regions have systematic velocity gradients. With $WISE$ released database, Class I and Class II candidates were identified within the CO clumps. The fraction of the Class I to the YSO candidates (Class I+Class II) is larger than 50% (50–60 %) in CWHRs, and less than 50 % (10–40 %) in CWOHRs. Our result clearly shows that effects from the H II regions can be seen in (1) spatial distributions of the clumps: filamentary or shell-like structure, (2) velocity structures of the clumps: absence of distinct velocity gradient, and (3) small spread in evolutionary stages of YSOs. We propose that the H II regions can trigger coeval cluster formation with a small spread in evolutionary stages of YSOs.

Exploring the Adolescent Stages of Massive Star Formation

Todd R. Hunter[1], Crystal L. Brogan[1], Claudia J. Cyganowski[2,6], Remy Indebetouw[1,3], Rachel Friesen[4], Claire Chandler[5]
[1] *NRAO / North American ALMA Science Center*
[2] *Harvard-Smithsonian Center for Astrophysics*
[3] *University of Virginia*
[4] *University of Toronto*
[5] *NRAO*
[6] *NSF Postdoctoral Fellow*

We present a K-band (23-25 GHz) imaging study of 22 massive protoclusters in 1.3 cm continuum and a diagnostic set of spectral lines using the recently-upgraded Karl G. Jansky Very Large Array (VLA). For the first time, this survey samples a wide range of massive star formation tracers simultaneously and at the same spatial resolution (~9000 AU). We detect compact ammonia cores in all of the fields, with many showing multiplicity and emission up through the (6,6) inversion transition, indicating high temperatures. Maser emission in the 25 GHz methanol ladder is present in at least 7 sources, as is strong non-thermal emission in the ammonia (3,3) transition. We also present Submillimeter Array (SMA) continuum and spectral line images of two of the targets (G35.03+0.35 and G11.92-0.61), revealing diversity in the properties of the ionized gas, dust continuum, and hot core molecular emission. Fits to the spectral profiles often require multiple components at different temperature and/or velocity, suggesting the presence of additional unresolved cluster members that are ripe for deeper exploration with ALMA. We have proposed follow-up observations of several targets at higher, matched resolution in bands 3 and 6 for Early Science Cycle 1.

Probing the Elusive Pre-Stellar Core Candidate

Doug Johnstone[1,2,3], Scott Schnee[4], Stella Offner[5], James Di Drancesco[2,3], Sarah Sadavoy[2,3]
[1] *Joint Astronomy Centre*
[2] *National Research Council Canada*
[3] *University of Victoria*
[4] *National Radio Astronomy Observatory*
[5] *Yale University*

Cataloging starless cores in star-forming environments is now relatively straightforward. Large surveys of sub-millimetre dust continuum taken with the Herschel Space Observatory and ground-based single-dish telescopes such as the JCMT are used to locate dense cores and these locations are examined for (a lack of) evidence for embedded protostars, usually using mid-infrared observations. A subset of these starless cores should evolve into protostars and are designated 'pre-stellar'. It remains an important goal of star formation studies to enumerate these sources, thoroughly investigate their physical behaviour, and compare against theoretical models.

We present the results of interferometric observations towards candidate pre-stellar dense cores in nearby molecular clouds, targeting sources with unusually large mass to Jeans mass ratios. We find that a significant fraction of supposedly starless cores actually contain embedded low-luminosity protostars. The remaining pre-stellar candidates, however, show little evidence of multiplicity, constraining fragmentation and suggesting that the origin of binarity (and higher order multiplicity) generally occurs at the proto-stellar, not pre-stellar, stage. Single-dish telescope observations of these candidate pre-stellar cores show significant evidence of infall, warranting dedicated ALMA observations. Finally, we compare the observational results with simulated observations of star-forming regions in order constrain formation scenarios.

The JCMT Legacy Survey: A Spectroscopic And Continuum Survey Of The Submillimetre Sky

Doug Johnstone[1,2,3], Gary Davis[1]
[1] *Joint Astronomy Centre*
[2] *National Research Council Canada*
[3] *University of Victoria*

A comprehensive survey of the submillimetre sky is underway at the James Clerk Maxwell Telescope (JCMT) using two state-of-the-art instruments: SCUBA-2 is a 10,000 pixel bolometer array, operating simultaneously at 450 and 850 microns, and HARP is a heterodyne array receiver operating between 325 and 375 GHz. The JCMT Legacy Survey (JLS) is comprised of seven survey projects, and ranges in scope from the study of nearby debris disk systems, the study of star formation in nearby molecular cloud systems and more distant structures in our Galactic Plane, to the structure and composition of galaxies in our local neighbourhood and the number and evolution of submillimetre galaxies at high redshifts in the early Universe.

The HARP components of the JLS are now complete and SCUBA-2 observations at the JCMT have commenced. In this poster Iwe will describe the JLS and its constituent projects, present some of the latest results to emerge from the JLS, and remark on the continuing importance of both continuum and molecular line surveys using single-dish sub-millimetre telescopes.

IRAC Identified Hershel Bright Galaxies in UDS fields

Sam Kim[1]
[1] *Pontificia Universidad Catolica de Chile*

24μ surveys using the MIPS instrument has been used in many studies to successfully identify high-redshift ULIRGs. However, the survey depth and size of the beam at this wavelength have limited identification rate. We identified 453 submm bright galaxies (67%) in UDS field by using mid-IR (Spitzer IRAC) data and likelihood ratio method. With the multiwavelength data from optical band to submm band data, we modelled spectral energy distribution to estimate physical quantities of sample galaxies. Large samples enables to calculate total IR luminosity function and star-formation rate. Luminosity function decreases at brighter side which is a unusual behavior compared to normal SMG luminosity function where the density shows peaks at $\sim 10^{13}$ $L_\odot$ before it declines.

Structure Analysis of Atomic and Molecular Gas in the Interstellar Medium and Its Interpretations

Sungeun Kim[1]
[1] *Department of Astronomy & Space Science, Sejong University, 143-747, Seoul, South Korea*

We review the current tools of determining structures that underlie in the interstellar gas and their implications for understanding the structures present in the interstellar dust, in our Galaxy and the external galaxies. The tools in the present study include cloud detection algorithms with temperature threshold, clump finding algorithms, the kernel principal component analysis, the spectral correlation function, the power spectrum analysis, complex analysis, and defining composite shells. We describe the different outcomes of the diverse tools of determining structures in the interstellar medium and the prospects for analyzing the following observations with the ALMA.

Band 6 and 7 CO observations of the molecular counterpart to HH 409 coming from HD 163296

Pamela Klaassen[1], Itziar De Gregorio[2], Satoko Takahashi[3], Eiji Akiyama[4], Edwige Chapillon[3], William Dent[2], Daniel Espada[4], Antonio Hales[2], Michiel Hogerheijde[1], Attila Juhasz[1], Geoff Mathews[1], Joseph Mottram[1], Mark Rawlings[5], Leonardo Testi[6,7] Ewine van Dishoeck[1,8]
[1] *Leiden Observatory, The Netherlands*
[2] *Joint ALMA Observatory, Chile*
[3] *ASIAA, Taiwan*
[4] *NAOJ, Japan*
[5] *NRAO, USA*
[6] *ESO, Germany*
[7] *INAF, Italy*
[8] *MPE, Germany*

HD 163296 is a ~ 4 Myr old Herbig Ae star which has dispersed most of its natal envelope, and is surrounded by a few 100 AU disk. It is also associated with HH 409 as seen in optical, UV and X-ray observations of this source. These HH knots are oriented perpendicular to the disk, have tangential motions of $< 0.5''$ yr^{-1}, and jet velocities between 250 and 360 km s^{-1}. We present ALMA Band 6 and 7 observations of CO (J=2-1 and 3-2, respectively) showing the molecular counterparts to the HH 409 knots. The CO knots are spatially coincident with the HH knots (given their proper motions), but have much lower radial velocities (< 30 km s^{-1}). The CO knots have not been previously detected because they are faint (peaks of < 100 mJy/beam), and were below the sensitivity limits of previous observations. The sensitivity of these ALMA Science Verification observations is such that we not only detect this structure, but have quantified the energetics of the knots, as described here.

Analysis of High-Resolution Dust Polarization Observations in Molecular Clouds

Patrick M. Koch, Ya-Wen Tang, Paul T.P.Ho
ASIAA, Taiwan

Dust polarization observations with the SubMillimeter Array (SMA) toward star forming regions are revealing detailed magnetic field structures that are both complex and organized with very distinct features. Collapsing cores, observed around 350 GHz with resolutions up to ~ 0.3 arcsec, have been our testbed cases to develop new techniques to analyze polarization data beyond imaging. In particular, it is becoming manifest that magnetic field orientations in molecular clouds show some correlation with the dust emission gradient directions. We propose a new method, which – in the framework of ideal MHD – connects the measured angle between magnetic field and emission gradient directions to the field strength. This method leads to maps of position-dependent magnetic field strength estimates. As a further important outcome of this technique, the local significance of the magnetic field force compared to the gravity force can be quantified in a model-independent way. We apply our technique to several SMA sources, and we outline the potential of future even higher-resolution polarization observations with ALMA to quantitatively constrain magnetic field properties in molecular clouds.

Discovery of the Fundamental Plane in Star Formation

Shinya Komugi[1], Rie Miura[2], Sachiko Onodera[3] et al.
[1] *Joint ALMA Observatory*
[2] *Chile Observatory, NAOJ*
[3] *Meisei University*

We report the discovery of two relations between five independent observables of the ISM at the scale of individual giant molecular clouds. The variables are the star formation rate (SFR) as traced by the Hα and 24μm, $\mathrm{CO}(J=1-0)$ intensity, $\mathrm{CO}(J=3-2)$ intensity, dust column density, and the $\mathrm{K_S}$ band surface density. These variables were identified using the principal component analysis on a larger set of variables, catalogued for a statistical sample of giant molecular clouds in the nearby galaxy M33 by the NRO45m and ASTE10m telescopes. The five variables comprise two well defined surfaces in three dimensional space. It is found that molecular clouds occupy distinct regions in the plane depending on their age. Projecting the surfaces to two dimensions can reproduce the Schmidt-Kennicutt (SK) law and other known relations, but the relation between dust and SFR are tighter than the classical SK law at our scale of $\sim$100 parsecs. We consider the relations a multi parameter star formation law in M33. Testing for the universality of such relations in other galaxies and environments will become an important part of extragalactic and Galactic studies with ALMA.

Unveiling the detailed density and velocity structures of the protostellar core B335

Y. Kurono[1], M. Saito[1], T. Kamazaki[1], K.-I. Morita[1], and R. Kawabe[1]
[1] *The Chile Observatory, National Astronomical Observatory of Japan*

We present an observational study of the protostellar core B335 harboring a low-mass Class 0 source. We performed combined imaging of single-dish and interferometer, using $\mathrm{H^{13}CO^+}(J=1-0)$ line emission data obtained with Nobeyama 45-m telescope and Nobeyama Millimeter Array (NMA). The combined image depict a dense envelope within the core. We found a reliable difference in the power-law index of the density profile between the outer and inner regions of the core; $n(r) \propto r^{-2}$ for $r \geq 4000\,\mathrm{AU}$ and $n(r) \propto r^{-1.5}$ for $r \leq 4000\,\mathrm{AU}$. Moreover, the dense envelope has a quite symmetrical velocity structure with a line broadening toward the center, especially prominent in the position-velocity diagram across the outflow axis. We consider that the core has an inner free-fall region and an outer region conserving the conditions at the formation stage of central stellar object. We performed model calculations of position-velocity diagrams, and well reproduce observational results in terms of the collapse of an isothermal sphere. Our results of model calculations suggest small inward velocity, $v(r)_{r\geq r_{\mathrm{inf}}} \sim 0\,\mathrm{km\,s^{-1}}$ in the outer core at $\geq 4000\,\mathrm{AU}$. We concluded that our data agree well with a quasi-static initial condition of gravitational collapse such as Shu's model.

Kinematics in Filamentary IRDC

Matias Lackington[1], Gary A. Fuller[1,2], Nicolas Peretto[3], Jaime E. Pineda[2,4]
[1] *University of Manchester, UK*
[2] *UK Alma Regional Centre Node, University of Manchester, UK*
[3] *CEA Saclay, France*
[4] *European Southern Observatory*

Infrared Dark Clouds (IRDCs), dense regions observed in absorption against the galactic mid-infrared background, provide candidates for the initial stages of massive star formation. One striking feature of star forming molecular clouds is that they show ubiquitous filamentary structure. This can be seen in optical extinction images as well as sub-millimeter emission from the dust and in the molecular emission from the gas. We have mapped in a range of spectral lines several filamentary structures identified from the recent catalogue of IRDCs detected with Spitzer. Initial results show that lines have supersonic linewidths ($\sigma > 0.8$ km/s). Overall our mapping suggests that the massive cores which form star clusters grow by accretion of material along the filaments, and may continue to accrete material even after the first stars are formed. The most remarkable result found in the maps made with the Mopra telescope is that *structured velocity gradients* appear intimately *related to star formation activity* (as probed by 8μm and 70μm emission) in IRDCs. Many of the densest and most actively star forming clouds appear in regions of the filaments where the velocity structure suggests converging flows of gas.

Magnetic Field Structure revealed through CO polarization in Massive Star-Forming Region DR21(OH)

Shih-Ping Lai[1], Josep Miguel Girart[2], Qizhou Zhang[3], Ya-Wen Tang[4], Keping Qiu[5]
[1] *National Tsing Hua University, Taiwan*
[2] *Institut de Ciéncies de l' Espai (CSIC-IEEC), Catalonia, Spain*
[3] *Harvard-Smithsonian Center for Astrophysics, USA*
[4] *Institute of Astronomy and Astrophysics, Academia Sinica, Taiwan*
[5] *Max-Planck-Institut für Radioastronomie, Germany*

We present linear polarization detections of CO (3-2) line and the inferred magnetic field structure toward DR21(OH). The data is part of the SMA Legacy Project – "Filament, Magnetic Fields, and Star Formation" which is aiming at imaging dust and CO polarization at 345 GHz for a large sample of massive filaments. Our new results of CO polarizations toward DR21(OH) are in general consistent with previous BIMA results (Lai et al. 2003), but provide more detailed magnetic field structure up to $\sim$1" resolutions. The CO polarizations are strongly detected and coherent in all outflow features, suggesting that the interplay between magnetic fields and outflows are important in shaping the outflow structure in DR21(OH).

APEX Observations of CO Emission from Southern Radio Galaxies

R.A. Laing[1], I. Prandoni[2], F. Senatore[2], H.R. de Ruiter[2], P. Parma[2]
[1] *ESO*
[2] *IRA-INAF*

We describe the results of our ongoing programme of observations of $^{12}CO(2 \rightarrow 1)$ emission from a small, volume-limited sample of Southern Radio Galaxies. We have observed the galaxies with the SHeFI instrument on APEX and find a high detection rate. Large masses of cold gas are preferentially associated with prominent, kiloparsec-scale dust discs and the line profiles indicate ordered rotation in several cases. We plan to observe the sample with ALMA in order to study the processes of fuelling and jet-induced feedback.

Performance of the AEM 12m Antennas

R.A. Laing[1] et al.
[1] *ESO*

Twenty-five of the 12m antennas to be used in the ALMA array will be designed and manufactured by the AEM Consortium in Europe. By the time of the meeting, we anticipate that 18 of these will have been conditionally accepted by the Joint ALMA Office, with 12 or 13 operational at the high site. The results of pre-acceptance testing at OSF will be described. The absolute and offset pointing, dynamical performance and reflector surface accuracy of the antennas have been tested extensively and shown to meet the stringent ALMA specifications. We will also show results of pointing and astro-holography tests at the high site.

SEST observations of southern IR luminous barred and interacting galaxies

N. Loiseau[1], et al.
[1] *XMM-Newton SOC, ESAC, Madrid*

We used the Swedish ESO Submillimeter Telescope (SEST) to study the mass, distribution and kinematics of the molecular gas in southern IR luminous nearby galaxies. Most of these galaxies were barred and or interacting with a companion. They were previously classified as Starburst, Liners or Seyferts. We analise the properties of these galaxies.

On the mysterious asymmetric ring observed in the young HD 142527.

François Ménard[1], P. Varnière[2], H. Méheut[2], S. Casassus[3], H. Canovas[4], C. Pinte[5], W.-F. Thi[5], G. van der Plas[3], S. Perez[3], M. Schreiber[4], B. Dent[6], A. Hales[6], A. Jordán[7], and the MAD collaboration
[1] *UMI-FCA (CNRS/INSU), Cerro Calán, Chile*
[2] *APC, Paris, France*
[3] *DAS, U de Chile*
[4] *Univ. de Valparaiso, Chile*
[5] *IPAG, Grenoble, France*
[6] *JAO, Santiago, Chile*
[7] *PUC, Santiago, Chile*

Transition disks around young stars feature an inner gap mostly devoid of continuum emission and an outer rim and disk that shine brightly in scattered light in the NIR and thermal emission in the Mid and Far-IR/mm. At the disk rim, models predict that physics very relevant for planet formation is taking place because of direct illumination from the central star and local radial gas pressure maximum. In this contribution we will discuss one of these features: the vortices where dust and gas are locally concentrated, possibly helping the formation of planetary embryos.
The observational signatures of the vortices will be estimated with a combination of advanced models including 3D radiative transfer and multi-fluid (gas+dust) hydrodynamical simulations and we will discuss where current state-of-the-art facilities, including ALMA, are expected to make a significant contribution. Finally, in the case of HD 142527, the model predictions for vortices will be compared to recent high angular resolution adaptive optics imaging in the NIR and ALMA cycle 0 data, with a particular emphasis given to the continuum emission properties that may be linked to the vortices (e.g., zonal changes in grain sizes & opacity, horseshoe shape).
Please note that some of the ALMA Cycle0 data are embargoed until Jan 3, 2013. This abstract is pending authorization from ALMA observatory. In the unlikely event it is denied, the ALMA cycle 0 data will not be presented but predictions and AO imaging will remain extremely relevant.

Calibrator Monitoring with ALMA: A Variability Study

N. Marcelino[1], E. Fomalont[1,2], T. A. van Kempen[2,3], S. A. Corder[1,2], D. Barkats[2], R. Kneissl[2], R. Lucas[2,4], A. B. Peck[1,2], R. Hills[2], E. Villard[2], M. Saito[2], A. Lundgren[2], A. Hales[2], and the CSV team
[1]*National Radio Astronomy Observatory, Charlottesville, VA, USA*
[2]*Joint ALMA Offices, Santiago, Chile*
[3]*Leiden Observatory, Leiden University, Leiden, The Netherlands*
[4]*Institut de Planétologie et dÁstrophysique de Grenoble, Grenoble, France*

Accurate calibration of ALMA data requires good knowledge of the fluxes and behavior of quasars used as calibrators. Since their fluxes vary both in time and frequency, it is important to monitor them regularly. In addition, it is vitally important to establish that the gain of the telescope is stable and that conversion of the detected signal to astronomical units is reliable, because the required accuracy of the flux scale for ALMA ES observations should be 5%, 10% and 20% at Bands 3, 6 and 7, and 9 respectively. Since June 2011 a sample of $\sim$40 strong and known quasars, distributed equally over the sky, have been monitored regularly (two-week to one-month basis). Using all the available data, we have performed a detailed study on the variability of the flux measurements in order to: (i) check on the stability of the system to reproduce the observed fluxes at different conditions (elevation, primary calibrator used, etc.); (ii) estimate flux errors when interpolating measurements in time and between bands; and (iii) find reliable secondary calibrators to transfer the absolute calibration scheme to the science target. These could be the most stable quasars as they lengthen the cadence for monitoring.

A study of the dust formation zone of IRC+10216

N. Marcelino[1], J. Cernicharo[2], A. Castro-Carrizo[3], M. Guélin[3], J. Pearson[4], M. Agúndez[5], P. Fonfría[6], J. R. Goicoechea[2]
[1]*National Radio Astronomy Observatory, Charlottesville, VA, USA*
[2]*Department of Astrophysics, CAB, INTA-CSIC, Madrid, Spain*
[3]*Institut de Radio Astronomie Millimétrique, Grenoble, France*
[4]*Jet Propulsion Laboratory, Pasadena, CA, USA*
[5]*Univ. Bordeaux, LAB, CNRS, Floirac, France*
[6]*Instituto de Astronomía, UNAM, México City, Mexico*

We present the preliminary results of ALMA ES Cycle 0 observations of the prototypical Carbon-rich evolved star IRC+10216. In total, we have covered 20 GHz between 255 and 275 GHz in Band 6. The data has been self-calibrated in order to improve the S/N ratio and properly calibrate phases, using narrow lines arising from the unresolved dust formation zone (angular resolution = 0.6"; dust formation zone = 0.2"). The observed spectral scan shows an impressive forest of lines not seen previously with the IRAM 30m telescope or the SMA. All these lines arise from an unresolved region and many of them are probably vibrationally excited lines of known species. However, the spectral distribution of lines also suggests new families of molecular species previously hidden to the largest single dishes and interferometers due to sensitivity limitations. The spatial distribution of several species, $H^{13}CN$, SiO and SiS will be discussed. The problems found during the data reduction will also be presented.

Physical and Chemical Conditions in Centaurus A

Mark McCoy[1], Juergen Ott[2], David S. Meier[1]
[1] *New Mexico Tech*
[2] *National Radio Astronomy Observatory*

Centaurus A (Cen A), at a distance of 3.6 Mpc, is the nearest active radio galaxy. This makes Cen A a very good laboratory for probing the feedback from an active galactic nucleus (AGN). Understanding this feedback is vital to determining the effect of AGN activity on star formation properties over time throughout the universe. We present the high resolution maps of six rotational transitions: ^{12}CO(2-1), ^{13}CO(2-1), ^{13}CO(1-0), C^{18}O(2-1), HCN(1-0), and HCO^{+}(1-0) toward the nucleus of Cen A. We discovered that these transitions trace two different components of gas. The HCN and HCO^{+} trace a high density nuclear region, while the CO isotopologues trace a moderate density arm-like region. The nuclear region is approximately 280 pc in diameter and has a maximum rotation rate of about 175 km s^{-1} corresponding to an estimated dynamical mass of $> 10^9\ M_\odot$, much larger than the supermassive black hole mass of $5.5 \times 10^7\ M_\odot$. The absence of CO isotopologue emission in the nuclear region could possibly be attributed to irradiation by UV/X-rays from the AGN preferentially photodissociating the CO isotopologues.

New CASA tasks

Arturo Mignano[1], Marcella Massardi[1]
[1] *INAF–IRA, IT–ARC*

We present new CASA functionalities that we are developing to help the user during the data calibration and analysis. Data calibration is not an easy work and the user should be provided with all the possible facilities to better disentangle between different calibrations strategies. In CASA, so far, it is possible to examine calibrators' data (baseline-based) and antenna solution (antenna-based), separately. We developed a task called "overplotsolution" to plot calibration curves over the calibrators' data and compare them. We examined ALMA M100 Science Verification data and here we show the results.
We are also developing a task to make statistics of the visibilities and to estimate scalar and vectorial flux densities and rms levels from the uv data (i.e. before doing images). For point sources this corresponds to measure flux densities and their errors. In all the cases they provide hints on the data quality. Together with the uv coverage and the Tsys distribution they could be used, in a later version to build a noise map and retrieve few key numbers that characterize the quality of the dataset, before calibrations be applied.

Can ALMA probe fundamental physics?

Arturo Mignano[1]
[1] *INAF–IRA (IT–ARC)*

The Standard Model of particle physics is a very successful theory and its predictions have been tested to high precision in laboratories around the world. A variation in the proton to electron mass ratio, μ, would manifest as shifts in the transition energies of molecules. By comparing laboratory transition energies with the values registered in spectra of the astronomical objects. possible variations can be probed over our entire observable Universe and through most of its history. A variation in μ can be tested through precise measurements of the relative radial velocities of narrow molecular lines observed in the cold interstellar molecular cores (Flambaum and Kozlov, 2007), Recently, Levshakov et al. (2008, 2009), Molaro et al. suggest a relative change of μ of about $\Delta\mu/\mu \sim 2 \times 10^{-8}$, possibly connected with two extremely different environments terrestrial and interstellar. Other molecular transitions (H_3O^+, CH_3OH) ranging in the mm and sub-mm frequencies have been proposed to assess such a shift. Here, last results and new ideas in the ALMA era are presented.

Chemical evolution models: The relation of H2/HI in the star formation rate

Mercedes Mollá [1]
[1] *CIEMAT*

A grid of chemical evolution models to interpret observations from spiral and irregular galaxies was presented in Mollá & Díaz (2005). Our multiphase model calculates separetely the formation of molecular clouds and the formation of stars from cloud-cloud collision. These two phases in the star formation process produces a delay which allows to reproduce very well the observed diffuse gas radial distributions in disks, the trends of diffuse gas densities along the Hubble Sequence and the correlation of the star formation rate with the total gas density. However the resulting molecular gas do not fit the data as well as the diffuse gas does. In this work we will show our preliminary results obtained with an updated grid of models where we try other prescriptions to form molecular gas and stars from them. The evolution with redshift of both gas densities will be obtained

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

M. Momose[1], A. Morita[1], Y. Okamoto[1], M. Fukagawa[2], T. Muto[3], M. Honda[4], J. Hashimoto[5], M. Tamura[5],, SEEDS/HiCIAO/AO188 Teams
[1]*Ibaraki University,* [2]*Osaka University,* [3]*Kogakuin University,* [4]*Kanagawa University,* [5]*National Astronomical Observatory of Japan*

We carried out polarization differential imaging (PDI) of the disk around the Herbig Ae star HD169142 in H-band with HiCIAO + AO188 installed on Subaru Telescope. Significant scattered light is detected in the regions of $0.2'' - 1.1''$ in radius. Azimuthally-averaged radial profile of PI in the inner ($r < 0.35''$) or outer ($r > 0.6''$) regions can be fitted well with a power-law of r^{-3}, but the absoulute value in PI of these two regions is quite different from each other. The r^{-3}-dependence can be explained by disk structure whose scale height $H(r) \propto r$ and surface density $\Sigma(r) \propto r^{-1}$, and the difference in absolute value of PI can be attributed to the difference in $H(r)/r$ that causes change in grazing angle at the disk scattering surface between the two power-law regions. The most straightforward explanation for such difference is discontinuity of surface density along the radius; if the surface density in the inner region is significantly lower, the scattering surface gets closer to the equatorial plane, making the grazing angle in the inner region smaller. Other structural discontinuity in the disk, such as those in dust growth and degree of dust sedimentation, can also account for the discontinuty seen in PI. In addition to the radial power-law distribution, non-axisymmetric patterns on smaller scales were also identified in the PI image. These may be due to perturbation of an unseen planet in the inner regions.

ALMA observations of the gaseous debris disk around the 30 Myr old HD 21997

Attila Moór[1], Attila Juhász[2], Ágnes Kóspál[3], Péter Ábrahám[1], Dániel Apai[4], Timea Csengeri[5], Carol Grady[6], Thomas Henning[7], Alanna Hughes[8], Csaba Kiss[1], Ilaria Pascucci[4]
[1]*Konkoly Observatory of the Hungarian Academy of Sciences*, [2]*Leiden Observatory*, [3]*Research and Scientific Support Department, European Space Agency*, [4]*Department of Astronomy and Department of Planetary Sciences*, [5]*Max-Planck-Institut für Radioastronomie*, [6]*NASA Goddard Space Flight Center*, [7]*Max-Planck-Institut für Astronomie*, [8]*University of California Berkeley*

Gas-rich primordial disks and tenuous gas-free debris disks are usually considered as two distinct evolutionary phases of the circumstellar matter. surrounded by dusty debris disks, measurable gas component. In our preparatory APEX survey, we discovered that the debris disk around the 30 million-year-old HD 21997 exhibits a detectable amount of molecular gas at millimeter wavelengths. Here we present the first spatially resolved interferometric continuum (at 870μm) and line (at the J=2-1 and J=3-2 transitions of CO) observations of this disk with ALMA. In the continuum the inner hole in the dust disk is clearly resolved. By simultaneously modelling the spectral energy distribution and the ALMA visibilities we successfully constrained the structure of the dust disk. We were able to detect spatially and spectrally resolved CO emission, indicating that the molecular gas is located in a disk in Keplerian rotation around the central star. Not only ^{12}CO, but ^{13}CO and C^{18}O were detected as well, pointing to a large amount of gas. Our first results suggest that the observed gas may have primordial origin posing a serious question to the current paradigm of disk evolution, since the age of the system significantly exceeds model predictions for disk clearing and the ages of the oldest transitional disks.

High Resolution Near-Infrared Images of Transitional Disks around SAO 206462 and MWC 758

Takayuki Muto[1], Carol A. Grady[2 3], Jun Hashimoto[4], Misato Fukagawa[5], Thayne Currie[2], Nagayoshi Ohashi[4], Motohide Tamura[4], and SEEDS/HiCIAO/AO188/IRCS Collaboration
[1]*Division of Liberal Arts, Kogakuin University*
[2]*NASA Goddard Space Flight Center*
[3]*Eureka Scientific*
[4]*National Astronomical Observatory Japan*
[5]*Departmant of Earth and Space Science, Osaka University*

We present the recent high-resolution near infrared polarized intensity images of the transitional disks around SAO 206462 and MWC 758 obtained by Strategic Exploration of Exoplanets and Disks with Subaru (SEEDS) consortium. We have obtained images with spatial resolution $\leq 0.1''$ and the inner working angle of $\sim 0.2''$. The spatial resolution of our images is comparable with that obtained by ALMA in the near future, and therefore our results serve as "pre-ALMA" observation despite at different wavelengths. We have clearly detected disks with non-axisymmetric spiral structures. We present one interpretation of the spiral features using the spiral density wave theory. We discuss what kind of physical properties of the disk can be derived from the model and what the model predicts for future observations. We also discuss the properties of possible embedded planets that might cause such features.

Commissioning Status of ALMA Polarization Observations

Hiroshi Nagai[1], Kouichiro Nakanishi[2,1], George Moellenbrock[3], Ed Fomalont[3,2], Edwige Chapillon[4], Richard Hills[2], Stuartt Corder[2]
[1]*National Astronomical Observatory of Japan*, [2]*Joint ALMA Observatory*, [3]*National Radio Astronomy Observatory*, [4]*Academia Sinica Institute of Astronomy and Astrophysics*

Polarization observation is a unique tool to probe the magnetic field morphology in various astronomical objects. ALMA polarization capability will open a new window for exploring the astrophysics in connection with the magnetic field. The polarization commissioning team has been working on the verification of instrumental polarization (D-term), which is a key part of polarization sensitivity, and development of the calibration plan. Recent results suggest that

1. mean on-axis D-term is about 1-2% in bands 3/6/7,
2. considerable frequency dependence of D-term (peak-to-peak amplitude $\sim 3\%$ at most) is seen in bands 3/6 but is less apparent in band 7.

We confirmed that the on-axis D-term was successfully calibrated at a level of 0.1% using the strong polarization calibrator with CASA v4.0. level of 0.1%, this remaining D-term was probably limited by the now mitigated closure errors. We also made an attempt to measure the off-axis D-term, and preliminary results show that the D-term might become larger with increasing the offset from the beam center. Overall results suggest that the polarization imaging at well under the 1% level is feasible for small angular size objects. We will keep continuing to improve the observing and processing procedures for a range of polarization calibration modes, including the investigations of frequency-, direction- and time-dependence of the D-term by Cycle 2.

The Building Blocks of ALMA: Science Processing of the Antennas ALMA System Integration Science Team (SIST)

Lewis Knee[1,2], Shin'ishiro Asayama[3,7], Paolo Calisse[4], Paulo Cortés[1,7], Cristian López[1], Theodoros Nakos[4], Neil Phillips[4], Pere Planesas[4,5,7], Richard Simon[1,7], Giorgio Siringo[4], Hiroshi Yatagai[3], Juan Pablo Colque[6], Kurt Plarre[6], Matias Radiszcz[6]

[1]*National Radio Astronomy Observatory, U.S.A.*, [2]*National Research Council of Canada*, [3]*National Astronomical Observatory of Japan*, [4]*European Southern Observatory*, [5]*Instituto Geográfico Nacional, Spain*, [6]*Associated Universities Incorporated*, [7]*Former Member*

The ALMA System Integration Science Team (SIST) in Chile is responsible for testing and verifying the performance of the antennas which make up the ALMA array. After almost four years of task, procedure, software development, and organizational work (in close collaboration with the ALMA Department of Engineering and the ALMA Commissioning and Science Verification Group), we have now entered into a phase of serial antenna processing, delivering one antenna every two weeks to the array. As of October 2012, we have delivered 48 antennas ($\sim$72%) of the total 66, including antennas of all design types used in the array. The SIST science processing programme, as part of the larger AIV project, is a successful example of' "assembly-line" production and verification of complex state-of-the-art astronomical radio antennas.

Synergies between ALMA and new low frequencies radio facilities

Rosita Paladino[1], Chiara Ferrari[2], Emanuela Orrù[3], Huib Intema[4]
[1] *Università di Bologna - Italian ARC*; [2] *Universiteè de Nice* ; [3] *ASTRON - Radboud University Nijmegen* ; [4] *NRAO - VLA*

Radio astronomy is entering an exciting era, with a number of new and upgraded radio facilities coming online, like ALMA, JVLA, e-MERLIN, LOFAR , or just starting up, like the SKA. The entire radio spectrum, from low to high frequencies, will be explored with unprecedented resolution and sensitivity, and our knowledge of the Universe will greatly benefit from this detailed view.
ALMA and low frequencies facilities will provide complementary perspectives on different phenomena. We present some possible synergies:

- In nearby galaxies the comparison between the non-thermal component, observed at low frequencies (ν < 1 GHz), with the thermal emission, traced by mm/sub-mm observations, can enlighten the role of magnetic field and cosmic rays in star formation processes.
- Some radio galaxies show evidence of a restarted activity, resulting from gas being accreted on to the central supermassive black hole. Millimetric observations will allow to look at the causes from the point of view of fuel availability to the central engine.
- The comparison between thermal and non-thermal cluster properties is crucial to achieve a clearer characterization of intra-cluster phenomena. Observations at low frequency are best suited for the detection of diffuse intra-cluster radio sources, while millimeter observations are favored for depicting shock regions.

The Structure of the Magnetic Field in Musca Dark Cloud

Nadili L. Ribeiro[1], Antonio Mario Magalhaes[1], Antonio Pereyra[2]
[1] *IAG - U. Sao Paulo*, [2] *Obs. Nacional, RJ*

Our goal is the study of the magnetic field (MF) structure of a pre-collapse structure of the interstellar medium - the Musca Dark Cloud (MDC), a nearby (200-250 pc), large (0.25° x 3°) filamentary cloud. A description of the MF, together with knowledge on turbulence and gravitational forces, is key to understanding the evolution of interstellar clouds. We have hence obtained linear polarization measurements in the H band (1.65μm) in Brazilian's 60 cm and 160cm telescopes located at OPD, in order to combine these with our earlier optical observations (Pereyra & Magalhaes 2004). We are then able to probe denser regions than what was possible in the optical.

Our studies in the optical band showed that the cloud is surrounded by a MF well aligned with the projected small axis of the cloud. Our H-band data show the same tendency in the inner parts of the MDC. The comparison between the V and H bands allow us to verify whether the same grains are polarizing the light throughout the cloud and if they are the same as those in the general ISM. Utilizing the dispersion of the polarization vectors, it is possible to estimate the MF intensity using a modified C-F method, from which the importance of the MF with regards to that of the gravity may be judged. From the structure function of the polarization, we obtain the correlation length of the MF.

ALMA will be crucial to study the influence of the MF through the condensations that exist along the MDC. It will provide the gas density and dynamics from atomic & molecular lines and the polarization from the continuum dust emission, which can be combined for an estimate of the MF in the condensing regions. In the end, this study will provide knowledge of the MF structures from the most external regions to the most dense ones, resulting in valuable information on the influence of the MF on the collapse of the cloud from large to small scales.

How do cool stars lose mass?

Anita Richards[1], Alain Baudry[2], Jan Brand[3], Sandra Etoka[4], Malcolm Gray[1], Liz Humphreys[5], Jeremy Lim[6],Wouter Vlemmings[7]
[1] *JBCA, University of Manchester, UK*, [2] *University of Bordeaux, France*, [3] *INAF, Bologna, Italy*, [4] *Hamburger Sternwachte, Germany*, [5] *ESO, Germany*, [6] *ASIAA, Taiwan; University of Hong Kong*, [7] *Onsala Space Observatory, Sweden*

Cool red supergiants and AGB stars return copious amounts of molecules and dust to the ISM. It is not clear how material from the photosphere of oxygen-rich stars is expelled to around 5 R* where sufficient dust forms for radiation pressure to drive the wind. Models suggest most dust should be destroyed in the ISM but AGB grains occur in meteorites. 22-GHz water maser imaging shows mass loss concentrated in dense clumps, which might shield grains. ALMA will resolve multiple water, SiO and other maser transitions, probing clumps and less-dense interclump gas, both sides of the dust formation zone, constraining physical conditions on sub-AU scales using new models by Gray et al. Cloud size scales with star size, suggesting an origin in convection cells or other stellar surface phenomena. New 5-cm images of Betelgeuse from e-MERLIN show hot spots and extensions, comparable to irregularities in deeper layers seen at shorter wavelengths where the optically thick radius is smaller. Observations with ALMA, the VLA and e-MERLIN, at successively longer wavelengths at time intervals corresponding to the propagation time between layers, will trace photospheric disturbances from <2 to >5 R*, distinguishing the signatures of convection or pulsation as the agents of levitation.

Fragmentation in Massive Star-forming Regions

Javier A. Rodón[1], Henrik Beuther[2], Quizhou Zhang[3] Peter Schilke[4]
[1] *European Southern Observatory, Chile*
[2] *Max-Planck-Institut für Astronomie, Germany.*
[3] *Harvard-Smithsonian Center for Astrophysics, USA.*
[4] *I. Physikalisches Institut, Universität zu Köln, Germany.*

In the last decade, we have started to spatially resolve the relatively small gas and dust condensations in high-mass star-forming regions that will eventually become a massive star or system. We call these condensations of sizes on the order of 0.01 pc “cores”, and by estimating their masses we can construct the so-called Core Mass Function (CMF) of a region, to compare with the IMF and try to determine the evolutionary process from core to star.
For massive star-forming regions, the relationship between the CMF and the IMF is not yet well understood. This is, among other factors, due to the fact that there are not many massive CMF determined. Even then, some of those few CMF seem to tell a story of evolution, by presenting different slopes than that of the Salpeter IMF while others, seem to be very similar to the IMF.
In this work we will show CMFs obtained for a group of massive star-forming regions with SMA and PdBI observations. These CMFs show different slopes, and we explain the possible significance this has on the evolution of the cores and the role ALMA will play in this research.

Observational Characteristics and Identification of First Core

Kazuya Saigo[1], Kengo Tomida [2], Koji Tomisaka [1]
[1] *National Astronomical Observatory of Japan*
[2] *Department of Astrophysical Sciences, Princeton University*

The formation of first cores is one of the most important and poorly understood in the star formation process. Forming between cloud core and stellar core phases (observational missing link of star formation processes), theoretical calculations predict first cores have very low luminosity ($sim0.01$ Lsun), low effective temperature (sim 30K), and are embedded deeply in the dense cores. In recent years, observation of the first core became accessible with increasing sensitivity in the sub-mm and mid/far-IR bands. The search for first core is ongoing, and as yet, has resulted in only a small number of candidate objects. Since the details of the observational feature are not known, we could not identify it. We present observational characteristics of first core. We model rotating first cores with 3D-RHD numerical simulations and obtain the ideal imaging maps or ideal line profiles by radiative transfer calculations. And we investigate the observational characteristics using the ALMA simulator etc. We find the first core can be identified using ALMA from HDO transition lines from surface shock-wave-heating layers (ALMA Band 6/7) in ALMA Cycle 2 (?) and also by direct generated imaging of dust continuum emission in ALMA Band 9/10 in ALMA Full Operation phase.

The nature of high redshift ULIRGs

Anna Sajina[1], Lin Yan[2], Greg Snyder[3]
[1] *Tufts University, USA*
[2] *Caltech, USA*
[3] *Harvard, USA*

I will present recent results on characterizing the infrared spectral energy distributions (SEDs) of 191 mid-IR selected $z \sim 0.3$-3.0 and $L_{\rm IR} \sim 10^{11}$-10^{13}L$_\odot$ galaxies, and study how their SEDs differ from those of local and high-z analogs. Infrared SEDs depend both on the power source (AGN or star-formation) and the dust distribution. Therefore, differences in the SEDs of high-z and local galaxies provide clues as to differences in their physical conditions. I will show that there is strong evolution in the SEDs between local and $z \sim 2$ IR-luminous galaxies, as well as that there is a wide range of SEDs among high redshift IR-luminous sources. Lastly, I will discuss possible explanations for this SED evolution as revealed in the morphology (based on HST NICMOS images) of our sources. I discuss some caveats on the interpretation of the observed SEDs based on theoretical SED models (based on GADGET+SUNRISE simulations). Lastly, I will address the possibilities for disentangling some of the uncertainties through future ALMA observations.

Infrared properties of dust in HII regions.

F. Salgado[1], A. G. G. M. Tielens[1], J. D. Adams[2]
[1] *Leiden Observatory, University of Leiden, P. O. Box 9513, 2300 RA Leiden, Netherlands*
[2] *Astronomy Department, 202 Space Sciences Building, Cornell University, Ithaca, NY 14853-6801, USA*

Dust grains are an important component of the universe, in extinction grains absorb UV and optical emission and reemit in the infrared. The infrared emission of dust is also used as a probe of the star formation rate in extragalactic studies. In cold enviroments dust plays a major role in the formation of molecules and photolectric heating of gas. However, dust properties are only understood in a phenomenological way by extrapolating properties from the Galactic ISM. The higher resolution and sensitivity of new infrared telescopes and instruments such as FORCAST (SOFIA) and PACS (Herschel Space Telescope) allow us to study the dust physical properties in great detail and with high accuracy. In our work, we combine observations from optical telescopes, Spitzer, SOFIA, Herschel, and radio telescopes in order to determine the spatial distribution, temperature, size, abundance and processing of different dust components (PAH, small and big grains). We focus our studies on compact HII regions, their surrounding photodissociation regions and molecular clouds. Here, we present unique results for the compact HII region W3(A) and Orion. Our dataset will be complemented with future FORCAST observations in five compact HII regions.

The Connection between Outflow Structure and Heating Mechanisms in Low-Mass Star Formation

D.M. Salter[1,2], L.G. Mundy[2], J.K. Jørgensen[3] and the Herschel DIGIT Embedded Source Team
[1] *Pontificia Universidad Católica de Chile, Departamento de Astronomía y Astrofísica, Santiago, Chile*
[2] *University of Maryland, Department of Astronomy, College Park, MD, USA*
[3] *University of Copenhagen, Niels Bohr Institute, Copenhagen, Denmark*

Recent Herschel results reveal highly excited CO ($J_U > 10$) emission lines toward a sample of young low-mass embedded protostars. The lines can be reproduced with radiative transfer models using a combination of UV- and shock-heated gas along the outflow cavity walls. The models predict correlations between the outflow structure and the relative contributions from each heating mechanism, but spatially and spectrally resolved CO observations are necessary to break model degeneracies and test predictions for the cavity wall conditions. Here we present new CARMA ^{12}CO (2–1), ^{13}CO (2–1), and C^{18}O (2–1) interferometric observations of 10 embedded sources that, combined with data from the literature, complete the cold dust and gas picture for our northern Herschel DIGIT embedded source sample. The data reveal outflow properties that span a range in opening angle, physical extent, orientation, and integrated line intensity. The observations are targeting the physical interaction of the outflow with the cavity walls to understand how energy is returned to the interstellar medium during star formation and assess how well our emerging outflow picture describes the full CO ladder. Future ALMA observations will help bridge the (rotational) energy gap between the cold gas probed by existing interferometers and the (unresolved) warm gas components revealed by Herschel.

ALMA images of a disk wind

Colette Salyk[1], Ke Zhang[2], Klaus Pontoppidan[3], Stuartt Corder[4], Geoffrey A. Blake[2]
[1] *NOAO*
[2] *Caltech*
[3] *STScI*
[4] *ALMA*

The process of star and planet formation is often envisioned as a series of discrete evolutionary stages (0–III) during which a core collapses (0), forms a disk and outflow (I), clears its envelope and reveals an optically thick protoplanetary disk (II) and, finally clears the disk, retaining only planets and second-generation dust (III). Objects in transition between two consecutive stages should also exist, and can provide particular insight into disk evolution. Recently, a new class of protoplanetary disk has emerged as a possible link between stages I and II, in which the envelope is largely dissipated, but where the disks produce significant low-velocity molecular outflows or winds. These so-called disk wind sources were first identified by the presence of strong IR molecular line emission, with spectrally-resolved line profiles too centrally-peaked to be fit by a protoplanetary disk alone. Here, we will present the exciting results of a search for a millimeter-wavelength counterpart to the IR-discovered molecular disk winds in a canonical disk wind source. We will also discuss the implications of this result on disk mixing, system evolution and any forming protoplanets.

The ALMA Ultra-deep Field: Predictions for Constraints on Galaxy Evolution Models

Kimberly Scott
North American ALMA Science Center, National Radio Astronomy Observatory

The source counts of galaxies detected at submillimeter/millimeter wavelengths provide strong constraints for modeling the evolution of galaxies. Indeed, the information gleamed from deep, wide-area surveys at these wavelengths taken with single-dish telescopes has provided important clues to the evolution of the most luminous, most massive galaxies in the Universe. However, these systems account for only ~20% of the total star formation activity at $z \sim 2$-3; understanding the evolution of the lower luminosity/lower mass systems (which are much more numerous) requires even deeper surveys, beyond the confusion limit reached by existing 10 m-class, single-dish telescopes. Here, I discuss how future "ultra-deep field" surveys with ALMA — which are already being proposed for Cycle 1 — can inform on outstanding questions on galaxy formation and evolution during the peak epoch of star formation.

Post-merger Signatures of Red-sequence Galaxies in Rich Abell Clusters at $z \leq 0.1$

Yun-Kyeong Sheen[1], Sukyoung K. Yi[2], Chang H. Ree[3], Jaehyun Lee[2]
[1] *Universidad de Concepción*
[2] *Yonsei Universtiy* [3] *Korea Astronomy and Space Science Institute*

We present post-merger signatures of red-sequence galaxies in four rich Abell clusters at $z \leq 0.1$ with deep optical images taken by Blanco 4-m telescope. Rich galaxy clusters are not a likely place to see frequent galaxy mergers because of large peculiar motion of the galaxies. Surprisingly we found that, however, the fraction of post-merger galaxies among red-sequence galaxies in the clusters is not much lower than that in the field (25% in our cluster sample (Sheen et al. 2012) vs. 35% in the field (van Dokkum 2005), while ongoing merger fraction is significantly lower in the cluster environment. In addition, it turned out that there is a lack of dependence of the post-merger fraction on the clustocentric distance. We interpreted this result as that the galaxies are carrying their post-merger signatures from their previous dark matter halo in which galaxy mergers could occur more easily. We also present star formation history of the post-merger galaxies derived from GALEX deep UV images. Lastly, our proposal will be introduced which is submitted for the ALMA Cycle 1 to investigate the gas content of the post-merger galaxies in clusters.

Classical Be and Herbig B[e] stars as potential ALMA targets

Stan Štefl[1]
[1] *ESO / JAO, Santiago, Chile*

Bright classical Be stars with gaseous circumstellar disks are popular targets for the near-IR and visual interferometry and spectro-interferometry. Although the disk geometry and inner and central disk dynamics are already well described at least for a few Be stars, radio data are still needed to model the external parts of the disks and to study their dissipation and interaction with the interstellar medium. Our APEX and CARMA observations confirm that Be stars with sufficient fluxes in the mm region can be reliably selected using near-IR interferometric observations and their modeling. For the closest Be stars, ALMA will bring direct images of their outer disks.
Although "hot" classical Be stars do not belong to high priority ALMA targets, the methods developed for their modeling can be well applied to pre-main sequence Herbig Be[e] stars, the proto-planetary disk of which are among the most attractive targets both for ALMA interferometry and spectroscopy.

Looking into the inner disk of TW Hya

Kengo Tachihara[1,2], Masao Saito[1,2], Bill Dent[1]
[1] *Joint ALMA Observatory*
[2] *National Astronomical Observatory of Japan*

As a result of the Scientific Verification (SV) observations of ALMA, we report the first detection of $HC^{15}N$ molecule from the TW Hya proto-planetary disk. TW Hya is known to be the nearest classical T Tauri star (~ 56 pc) surrounded with a proto-planetary disk composed of rich gas and dust. SV datasets in band 3,6, and 7 were taken with 8-10 numbers of the ALMA 12m antennas with a compact configuration, resulting in spacial resolutions of $3.5''$, $2.6''$, and $1.6''$, respectively. In addition to the major molecular lines of CO, HCO^+, and HCN, we have detected in band 7 the $HC^{15}N$ (J =4–3) line, for the first time from a proto-planetary disk. The velocity structure of the line is consistent with the Keplarian rotation as seen in the other lines. The $HC^{15}N$ emission appears, however, to have smaller spatial extend, and its integrated line over the disk shows double-peaked profile, unlike the other molecular lines. The double-peak profile indicates that $HC^{15}N$ emission traces the inner region, e.g. ≤ 100 AU, thanks to its lower optical depth.

Polarization in Star Forming Clouds at mpc Angular Resolution

Ya-Wen Tang, Patrick M. Koch, Paul T. P. Ho
Institute of Astronomy and Astrophysics, Academia Sinica, Taipei, Taiwan

We will present our current studies of the magnetic (B) field in the star forming cores and in the envelopes of molecular clouds. Dust grains are known to align with their shorter axes parallel to the field lines in most circumstances. The plane-of-sky projected B field integrated along the line of sight can be traced by rotating the detected polarization of the thermal dust emission by 90^{o}. In order to trace the B field, dust continuum at wavelengths of 870 μm and its linearly polarized emission were observed with the Submillimeter Array (SMA). The B morphologies are resolved with an angular resolution up to 0.3". Dense structures with a number density 10^5 to 10^7 cm^{-3} are traced. The B morphologies of sources at different evolutionary stages, from the collapsing core (W51 e2 and part of Orion BN/KL) to the ultra-compact HII region G5.89-0.39 will be presented. We will further present a new case study of the B morphologies toward the W51 North region, combining field structures at three different physical scales. In a sequence of increasingly higher resolution observations - from CSO/JCMT single dish at 2 pc to the SMA highest resolution at about 10 mpc - it becomes manifest how the field morphologies change from the envelope surface layer to the inner core and disk. Structures vary from uniform to cometary and hourglass-like. We quantify these changes, which provide an evidence that the interplay of the B field with other forces evolves with scale. These results have the highest angular resolution which can be achieved with current interferometers in the sub-millimeter domain. With the coming capabilities of ALMA, we expect to trace the B field morphologies with higher angular resolution, higher sensitivities and more complete uv sampling.

The ALMA view of the cool dust in an extreme low-metallicity starburst

L. Hunt[1], S. Garcia-Burillo[2], F. Combes[3], R. Maiolino [4], K. Menten[5], A. Weiss[5], P. Caselli[6], L. Testi[1,7], V. Casasola[8], Ch. Henkel[5]

[1] *INAF-Osservatorio Astrofisico di Arcetri, Italy*, [2] *OAN, Madrid, Spain*, [3] *LERMA, Obs-Paris, France*, [4] *IoA Cambridge University, UK*, [5] *MPIfR Bonn, Germany*, [6] *Leeds University, UK*, [7] *ESO, Germany*, [8] *INAF-IRA, Italy*

The starburst in SBS 0335-052E occurs in extreme conditions, dominated by Super Star Clusters (SSCs) which have formed in a relatively pristine interstellar medium (ISM) (12+logO/H=7.2). We have performed ALMA Cycle 0 observations to detect the cold dust associated to the star formation in this tiny galaxy in order to help understand how metal enrichment and dust production proceed in early stages of galaxy formation. SBS 0335-052 hosts six Super Star Clusters, spread over roughly 2.6 arcsec in diameter. Most of the star-formation activity occurs in the two brightest clusters, which host almost 10000 O stars in a compact region unresolved by the HST. Our pre-ALMA analysis of the spectral energy distribution (SED) of this SBS 0335-052E suggests that the dust mass and dust-to-gas ratio (DGR) is highly uncertain; compared with the HI mass, the dust-to-gas ratios (DGRs) range from 3×10^{-7} to 2×10^{-5}, much lower than predicted by a linear extrapolation of the DGR variation with metallicity. With ALMA we detect, for the first time, continuum emission at 850 μm, at a level much lower than originally expected. We present the ALMA results and we discuss their implications in the context of low metallicity star formation in the Local Universe.

ALMA Observations of the IR-bright Merger VV114

T.Saito[1,2], D.Iono[2], J.Ueda[1,2,5] M.Yun[3], R.Kawabe[2,4], D.Espada[2], Y.Hagiwara[2], M.Imanishi[2], K.Motohara[1], K.Nakanishi[2], H.Sugai[2],and K.Tateuchi[1]
[1] *University of Tokyo, Japan*
[2] *National Astronomical Observatory of Japan, Japan*
[3] *University of Massachusetts, USA*
[4] *Joint ALMA Observatory, Chile*
[5] *Harvard-Smithonian Center for Astrophysics, USA*

We present preliminary 12CO(1-0), 13CO(1-0), 12CO(3-2), HCO^+(4-3) and HCN(4-3) maps of the IR-bright late stage merger VV114 obtained during cycle 0 of ALMA. The main objective is to understand the response of the diffuse and dense gas when two gas rich galaxies collide and merge. We find new CO(1-0) tails and arms emanating from both galaxies with a significantly broader emission at the overlap region of the two galaxies, and this also coincides with high 13CO/12CO ratio. The nucleus of VV114E shows a compact and broad HCO^+ and HCN emission that also coincides with the bright submm continuum peak, suggesting the existence of a buried AGN surrounded by dense gas. VV114E also shows significant evidence for extended dense gas that is consistent with the star formation region traced in Pa alpha emission. These new ALMA data demonstrate the importance of observing both the diffuse and dense gas in order to obtain a comprehensive view of the physical processes that occur during a major merger event.

The anti horseshoe: HCN chemistry in HD 142527

Gerrit van der Plas[1], Simon Casassus[1], Francois Menard[2], W.-F. Thi[3] and the MAD collaboration
[1] *Universidad de Chile*
[2] *UMI-FCA (CNRS/INSU), Cerro Calan, Chile*
[3] *IPAG, Grenoble, France*

The horseshoe shape of the disk around HD 142527 as seen with ALMA in the dust continuum prompts a wide variety of explanations (planet-induced dynamical clearing, large scale vortices, azimutal grain size segregation). ALMA Observations of molecular gas in this disk show the opposite: an "anti horseshoe" that peaks at the minimum of the continuum emission. We explore the possible explanations and use our observations to test models for the horseshoe shape of the dust continuum emission.

Please note that some of the ALMA Cycle 0 continuum data are embargoed until Jan 3. This abstract is pending authorization from ALMA observatory. If denied, the ALMA cycle 0 continuum data will not be used.

Building the Calibrator Database of ALMA

Tim A. van Kempen[1,2], E. Fomalont [1,3], N. Marcelino[3], D, Barkats [1], S. A. Corder[1,3], R. Lucas [1,4], A. B. Peck[1,3], R. Kneissl[1], R. Hills [1], E. Villard [1], M. Saito[1], A. Lundgren[1], A. Hales[1] and the CSV team
[1]*Joint ALMA Offices, Santiago, Chile*
[2]*Leiden Observatory, Leiden University, Leiden, The Netherlands*
[3]*National Radio Astronomy Observatory, Charlottesville, VA, United States*
[4]*Institut de Planétologie et d'Astrophysique de Grenoble (IPAG), Grenoble, France*

A basic ingredient for optimal calibration of scientific ALMA observations, both before and during the executions of scheduling blocks, is accurate knowledge of the position, flux density, shape and other physical parameters of calibrators. ALMA alternates observing scans between a quasar and a scientific target to follow and remove the instrumental temporal gain and phase changes during observations. This calibration is critical to produce high quality data. However, the properties of many quasars at (sub)millimeter wavelengths are not well known. Above 260 GHz (Band 6), only the observational efforts of SMA are within the same frequency range and sky coverage. In the southern sky (below -40 degrees) the situation is worse; Only quasars at frequencies extending to 50 GHz have been systematically observed by ATCA. Although positions are often well constrained from VLBA/VLBI or other radio interferometers, the spectral index between the cm, millimeter and sub-millimeter is virtually unexplored. To this end, we present the results of a year-long effort during the Commissioning and Science Verification of ALMA to observe over 500 quasars, using known positions, at frequencies in Bands 3, 6 and 7. We derive flux densities, spectral indices, temporal variations and other properties necessary for accurate calibration.

Class I methanol masers with ALMA

Maxim Voronkov[1], Simon Ellingsen[2], James Caswell[1], Shari Breen[1], James Green[1]
[1]*CSIRO Astronomy and Space Science, PO Box 76, Epping, NSW 1710, Australia*
[2]*University of Tasmania, GPO Box 252-37, Hobart, Tasmania 7000, Australia*

Methanol masers are a common phenomenon in the star-forming regions. The collisionally pumped (or class I) masers are still relatively poorly studied in contrast to their radiatively pumped (or class II) counterparts. The majority of candidate maser transitions in the frequency range opened up by ALMA belongs to class I. Based on the surveys with the Australia Telescope Compact Array (ATCA) we describe observational properties of these masers and make predictions for the high-frequency transitions. Some of them, including known masers at 229 and 278 GHz are likely to have multiple maser spots scattered over an area often up to 1 arcmin in extent. Given their strength and ubiquitous appearance in high-mass star-forming regions, these masers are potentially a significant contaminant in continuum measurements. On the other hand, rare masers are expected to arise from a single compact location. The most promising targets for such masers are G343.12-0.06 and G357.97-0.16.

[CII] line emission in massive galaxies 1.3 Gyr after the Big Bang

Jeff Wagg[1,2], Chris Carilli[3], Tommy Wiklind[4], Daniel Espada[5], Alison Peck[3], Dominik Riechers[6], Fabian Walter[7], Al Wootten[3], Manuel Aravena[2], Denis Barkats[4], Juan Cortes[4], Richard Hills[1,4], Jacqueline Hodge[7], Violette Impellizeri[4], Daisuke Iono[5], Adam Leroy[3], Sergio Martin[2], Mark Rawlings[3], Roberto Maiolino[1], Richard G. McMahon[8], Kim S. Scott[3], Eric Villard[4], Catherine Vlahakis[4]
[1] *Cavendish Laboratory*
[2] *ESO*
[3] *NRAO*
[4] *JAO*
[5] *NAOJ*
[6] *Cornell*
[7] *MPIA*
[8] *IoA*

Massive galaxy formation in the young Universe is often accompanied by strong thermal dust continuum emission redshifted to submm and mm-wavelengths, arising from extreme bursts of star-formation and/or an active galactic nucleus. Spatially resolving this emission on sub-arcsecond scales to determine the source of the dust heating is only possible using sensitive interferometers like the PdBI and ALMA. Furthermore, these ground-based instruments allow us to study the ionized atomic tracers such as ionized carbon ([CII]) line emission redshifted to the submm and mm atmospheric windows for galaxies that existed during the first half of the age of the Universe. [CII] line emission is typically the brightest line in the FIR spectra of galaxies, and provides an unobscured view of the kinematics of interstellar gas in early galaxies. Here, I will present observations of thermal dust continuum and [CII] line emission in the luminous quasar, submm galaxy system, BR1202-0725 at $z = 4.7$, obtained as part of commissioning and science verification of ALMA. These results highlight the spectral line sensitivity of ALMA at band 7, and confirm the potential of this incredible new instrument for future studies of the interstellar medium in high-redshift galaxies.

Characterizing the transitional disk around T Chamaeleontis

N. Huelamo[1], I. de Gregorio-Monsalvo[2], M. Ireland[3]
[1] *Center of Astrobiology (INTA-CSIC), Madrid, Spain*
[2] *European Southern Observatory (ESO), Garching, Germany*
[3] *Macquarie University, Australian Astronomical Observatory, Sydney, Australia*

T Chamaleontis is a young star surrounded by a transitional disk. High sparse aperture masking observations obtained with NACO/VLT revealed the presence of a substellar companion candidate within the disk gap, the first substellar candidate within a transitional disk. To characterize the disk around the source, we have performed high angular resolution millimeter observations that have allowed to study the content of cold dust and compare it with theoretical predictions.
We were granted with Cycle-0 ALMA time to study the gas and dust content of the disk. We plan to show the first results on these observations at the time of the meeting if we receive the data products of this interesting source on time.

Prospect for revealing the problem of the angular momentum transport in the star formation physics by observation

K. Kiyokane[1], M. Saito[2], K. Saigo[2], Y. Kurono[2], M. Momose[3], T. Tsukagoshi[3],and NRO45m SF-Legacy Team
[1] *The University of Tokyo, Japan. (kazuhiro.kiyokane@nao.ac.jp)*
[2] *National Astronomical Observatory of Japan*
[3] *Ibaraki University, Japan*

Recently, the radial distribution of density structure of a low-mass dense core has been extensively investigated from the milli-/submillimeter continuum observations. We, however, have not yet understood the radial distribution of the specific angular momentum in a dense core, which is a crucial parameter to determine the evolution of a forming star. Although several dense core surveys have been conducted so far these studies have not revealed the radial distribution of the specific angular momentum because a rigid rotation in the dense core is in most cases assumed. We therefore mapped a 6'x6' region in $C^{18}O$(1-0) with 0.1 km/s resolution toward the low-mass protostellar core L1527 with the Nobeyama 45m Telescope. A $C^{18}O$ is found to be roughly centered on the protostar and we found a velocity gradient in the core whose direction is not perpendicular to the outflow direction. Although a newly found $C^{18}O$ core near L1527 affects the observed velocity structure of L1527, the velocity gradient of L1527 agrees with the previously observed one in $H^{13}CO^{+}$(1-0). By comparing with previous interferometer and single dish observations, we will discuss the radial dependence of angular momentum structure of L1527 on from dense core scale to disk scales.

MADCUBA_IJ: A new software for Molecular Analysis

S. Martín[1], Martín-Pintado, J.[2], Blanco Sánchez C.[2], Villacaña Pedraza I. [2], Báez Rubio A.[2]
[1] *European Souther Observatory, Chile*
[2] *Centro de Astrobiologia (CSIC-INTA), Spain*

The unprecedented sensitivity of ALMA is delivering an enormous increase in the observable chemical complexity of the Universe. In order to deal with such datasets, it becomes necessary the use of dedicated tools for both data handling and analysis.
We present the new software MADCUBA_IJ (Madrid Data Cube Analysis). MADCUBA_IJ is a graphical tool for the analysis of astronomical images, data cubes and spectra accepting images in FITS format or imported from the native format from many different telescopes. MADCUBA_IJ provides multiple data handling GUIs.
Within the MADCUBA_IJ package, the SLIM application (Spectral Line Identification and Modelling) is a dedicated tool to identify the analyze molecular spectral lines. SLIM has a standalone molecular database including all major available spectroscopic databases. One of the main SLIM capabilities are the tools to perform multi-transition fit to wide band spectra by adjusting parameters of column density, excitation temperature, radial velocity, line width and source size under LTE approximation but including opacity effects. Such fit can be performed in either interactive or automatic modes. Additionally, SLIM provides simple GUIs to perform Gaussian fits or calculate integrated intensities to observed spectral features and to use this informatin to calculate physical parameters of column density and excitation temperatures.

Evaluation of pointing errors of ALMA ACA antennas

Ayumu Matsuzawa[1], Masao Saito[2], Satoru Iguchi[2]
[1] *The Graduate University for Advanced Studies*
[2] *National Astronomical Observatory of Japan*

Pointing errors of a radio telescope antenna are one of the serious problems in observations because accuracy of observed intensity is degraded by pointing errors. The offset pointing errors of the Atacama Compact Array (ACA) antennas are required to be smaller than 0.6 arcsec rss that is 1/10 of the field of view of the ACA 12-m antenna at 950 GHz. The pointing errors of the ACA antennas were measured in the site erection facility at an elevation of 2900 m using an optical pointing telescope (OPT) mounted on the back up structure. Our goal is to accurately estimate the pointing errors of antenna origin. However, OPT measurements contain three error components; origin of the ACA antenna, origin of atmosphere (optical seeing), origin of OPT itself. In the present research, we conducted all-sky pointing, offset pointing, a continuous tracking, fast switching and servo measurement at constant velocities under various conditions such as wind load and thermal load. We will present a currently developing method to estimate pointing errors of only antenna origin.

The survival of molecules in cavities of transition disks

Simon Bruderer[1], Ewine F. van Dishoeck[1,2]
[1] *Max Planck Institute for Extraterrestrial Physics, Garching, Germany*
[2] *Leiden Observatory, Leiden University, the Netherlands*

Planet formation is closely related to the evolution of protoplanetary disks. Before protoplanetary disks disperse, they enter a transition phase where a gap in the dust surface density opens up. Different mechanisms for the origin of this gap have been suggested, including the clearing up by a newly formed planet, grain growth or photoevaporation. The amount of gas inside such gaps is still unclear, yet this is key to distinguish between the different scenarios. Since proto-planetary bodies evolve significantly in the transition disk phase, knowledge of the disk dissipation process is crucial for the understanding of planetary system evolution.

ALMA allows for the first time to spatially resolve the gas content of cavities. To analyse the new ALMA observations and study the physical/chemical composition of gas inside a gap, we have developed new radiative thermo-chemical models of the inner disk. The models are based on Bruderer et al. (2012) and solve for the chemical abundance self-consistently with the dust radiative transfer, thermal balance and molecular/atomic excitation. The models are used to constrain the conditions that allow molecules to survive inside dust cavities as well as the chemical composition of the gas that may become part of the atmospheres of forming giant planets. We furthermore present ALMA predictions from a grid of transition disk models.

Gas and dust evolution models for transitional disks: the case of SR21

P. Pinilla[1], T. Birnstiel[2], C.P. Dullemond[1], E.F. van Dishoeck[3,4], S. Bruderer[3], N. van der Marel[4]
[1] *Universität Heidelberg, Zentrum für Astronomie, Germany*
[2] *University Observatory Munich, Germany*
[3] *Max Planck Institute for Extraterrestrial Physics, Garching, Germany*
[4] *Leiden Observatory, Leiden University, the Netherlands*

One of the most exciting theories to explain the lack of warm dust in the inner regions of transition disks is the dynamical interactions with planet(s), which makes these disks to be potential signposts of planets and interesting laboratories for studying processes related to planet formation. One of the oldest mysteries in the core accretion theory is how micron-size particles grow to planetesimals, in spite of fragmentation collisions and rapid inward drift of dust bodies. The idea of long-lived pressure bumps has been studied as a solution to trap dust particles and transition disks are prime cases for testing this idea. A single pressure bump in the outer edge of the gap is expected as a consequence of the significant depletion of the gas surface density when a massive planet is interacting with a disk (Pinilla et al. 2012, A&A 545, A81).

In this poster, we present gas and dust evolution models for transition disks and we explore the case of SR21 considering two massive planets with different properties interacting with the disk. This model is stimulated by VLT-CRIRES observations of CO 4.7 micron emission which reveal a warm gas ring at ∼7 AU radius, well inside the dust cavity with a radius of ∼36 AU (Pontoppidan et al. 2008, ApJ 684, 1323). With the different model assumptions considered in this work, we may explain the presence of gas inside the disk and whether or not the disk has dust close to the star or a completely empty hole. ALMA is the key to testing our models in two ways. First, by calculating the difference of the mm-slope inside and outside these trapping regions, we can test if transitional disk features are indeed regions where dust accumulates and grows over mm-sizes. Second, ALMA can reveal directly the bulk of the gas inside and outside the dust hole through CO emission.

Directly tracing the CO-snowline of HD 163296 with DCO^+

Geoffrey S. Mathews[1], Pamela D. Klaassen[1], Attila Juhasz[1], Daniel Harsono[1], Eiji Akiyama[2], Edwige Chapillon[3], William Dent[4], Ewine van Dishoeck[1,5], Daniel Espada[2], Itziar De Gregorio[4], Antonio Hales[4], Michiel Hogerheijde[1], Joseph C. Mottram[1], Mark Rawlings[6], Satoko Takahashi[3], Leonardo Testi[7,8]
[1] *Leiden Observatory, Leiden University, PO Box 9513, 2300 RA, Leiden, The Netherlands*
[2] *NAOJ, Japan* [3] *ASIAA, Taiwan* [4] *Joint ALMA Observatory, Chile* [5] *MPE, Germany* [6] *NRAO, USA* [7] *ESO Garching* [8] *INAF, Italy*

HD163296, a nearby (∼122 pc), young (∼4 Myr), disc-bearing A star, has long served as a prototype for the study of protoplanetary material due to its bright emission in both continuum and molecular lines. Here, we present high resolution (∼0.5”) ALMA Band 7 observations of the J=5-4 transition of DCO^+, as well as the J=4-3 transition of both the parent ion HCO^+ and the $H^{13}CO^+$ isotopologue. HCO^+ emission extends up to 3” (~ 360 AU). $H^{13}CO^+$ is also detected, though with a factor of ∼5 to 20 lower intensity. DCO^+ emission originates in a ring with a radius of approximately 150 AU, corresponding to the ∼20 K CO freeze-out region. We determine the density structure of HCO^+ and DCO^+, evaluate formation scenarios of DCO^+ in this disk, and examine their implications for disc chemistry. These data are part of Science Verification project 2011.0.000010.SV.

Deutero-ammonia (NH_2D) in BN/KL

A. Wootten[1], C. Favre[2], N. Brouillet[3], D. Despois [3], T. Jacq[3]
[1] *NRAO*
[2] *U. Michigan*
[3] *LAB, U. Bordeaux*

High resolution images of deutero-ammonia towards the OMC1 core region are presented. The lines imaged emanate from several different transitions at moderate excitation. Ammonia may become deuterated in cold gas or on grains but there is no chemical path leading to deuteroammonia in the warm gas characterizing the Orion molecular clouds. These data delineate the physical and chemical properties of the newly released gas and by inference of the gas which was frozen out onto the grains during times past. Our data includes EVLA images at high resolution (1.8"x1.4") of the OMC1 core region in the medium-excitation (E_{lower}=92K) 3_{13}-3_{03} line of para-NH_2D at 43.04 GHz. We compare these images to ones obtained by analysis of ALMA Science Verification data at 1.3mm which contains the $N_{\rm H2}J = 3_{22} - 3_{12}$ and $J = 3_{22} - 3_{12}$ lines (E_{lower}=109K) at 216.56272 and 239.84808 GHz respectively.

ALMA Observations of the Outflow from Source I in the Orion-KL Region

Luis A. Zapata[1]
[1] *Centro de Radioastronomía y Astrofísica, UNAM, México.*

I present sensitive millimeter SiO (J=5-4; ν=0) line observations of the outflow arising from the enigmatic object Orion Source I made with the Atacama Large Millimeter/Submillimeter Array (ALMA). The observations reveal that at scales of a few thousand AU, the outflow has a marked "butterfly" morphology along a northeast-southwest axis. However, contrary to what is found in the SiO and H_2O maser observations at scales of tens of AU, the blueshifted radial velocities of the moving gas are found to the northwest, while the redshifted velocities are in the southeast. The ALMA observations are complemented with SiO (J=8-7; ν=0) maps (with a similar spatial resolution) obtained with the Submillimeter Array (SMA). These observations also show a similar morphology and velocity structure in this outflow. I discuss some possibilities to explain these differences at small and large scales across the flow.