The Submillimeter Array (SMA) is a pioneering radio-interferometer dedicated to a broad range of astronomical studies including protostellar disks and outflows; evolved stars; the Galactic Center and AGN; normal and luminous galaxies; and the solar system. Located on Mauna Kea, Hawaii, the SMA is a collaboration between the Smithsonian Astrophysical Observatory and the Academia Sinica Institute of Astronomy and Astrophysics.

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1 From the Director

Following its dedication in November 2003, the SMA accepted observing proposals from scientists within the CfA, ASIAA, UH, and the wider astronomical community, and scheduled observations began. Since that time we have been in a period of transition from that of an experimental facility to a world-class facility conducting scheduled astronomical observations on a regular basis.

During the past several months we have been concentrating on bringing all eight antennas into routine operation with the goal of offering consistent system performance throughout the lowest observing frequency bands of the SMA. While we recognize the unique nature of the higher frequency bands of the SMA, and indeed we ran a successful 650 GHz campaign during February 2005, we also see the need to perfect the instrument in the lower frequency bands where much of the observing occurs. To this end the refit of antenna 8, which comprised numerous modifications and upgrades to both antenna and receiver hardware, was completed successfully at the beginning of the year. The cryostat in antenna 5 was replaced with a unit that included the second of the 400 GHz receivers, and antenna 4 was brought back into operation following a series of equipment problems arising from a lightning strike. In fact, a large fraction of recent observations have been made with the full eight-element array. During the coming semester antenna 7 will be taken off-line to undergo a similar refit to that of antenna 8.

Once this work has been completed no other major refits are planned. Apart from scheduled maintenance and equipment upgrades, we should be able to field an eight element array for much of the time which will be a benefit to all observers.

Ray Blundell
# 2 Science Highlights

## 2.1 Small scale shocks in low-mass protostars

One of the interesting questions in present-day star formation is whether deeply embedded low-mass protostars have “hot cores” similar to those known from the study of high-mass protostars (e.g., Ceccarelli et al., 2000, Schöier et al. 2002). In its early stages, the central protostar is expected to radiatively heat its surrounding inner envelope, and if the temperature close to the protostar becomes high enough \((\sim 100 \text{ K})\) the icy mantles of dust grains might evaporate triggering a chemistry in which, for example, high abundances of complex organic molecules form on the dust grains (e.g., Cazaux et al. 2003). It is also in these stages, and at these scales, that protoplanetary disks form. It is therefore of great importance to establish the presence and chemistry of these “hot core” regions, as the chemistry there might directly reflect the composition of the disks. Due to the low luminosities of the central protostars these inner regions are small, typically less than 200 AU in diameter \((1-1.5''\) for nearby star forming regions). Single-dish studies of low-mass protostellar hot cores are therefore problematic: the hot core region is severely beam diluted and any observed molecular species might be affected by the chemistry in the outer, large scale envelope. For example, outflows are likely to play an important part of regulating the chemistry of protostellar envelopes with species such as CH\(_3\)OH known to be greatly enhanced in shocks related to outflows (e.g., Bachiller et al. 1995).

The SMA is an excellent instrument for studies of these inner regions: First, previous studies based on lower excitation lines do not probe deep inside the envelope since those lines are sensitive to the chemistry in the outer cold regions and tend to become optically thick. In the 325-365 GHz atmospheric window, a wealth of molecular transitions constrain the chemistry in the dense \((\sim 10^{17} - 10^{18} \text{ cm}^{-3})\) and warm \((\sim 50 - 100 \text{ K})\) material within the envelope. At the same time, the innermost regions of the envelopes where the temperature increases above 100 K are heavily diluted in a single-dish beam \((< 2'' \text{ size compared to typical single-dish beam sizes of 10-20'')}.\) Typical SMA observations resolve the emission down to these scales and make it possible to disentangle the emission from the envelope and circumstellar disk. Finally, since the dust continuum flux scales with frequency as \(\nu^2\) or steeper, submillimeter observations are well suited for probing the dust in protostellar disks - and thereby establishing their presence and measuring their properties, such as mass.

We have undertaken a survey of a sample of 9 deeply embedded protostars with the Submillimeter Array, “Proto-stellar Submillimeter Array Campaign (PROSAC)\(^1\).” These sources have been observed systematically in a wide range of lines and continuum in the frequency range of 218-355 GHz from November 2004-December 2005. They were selected from a large single dish survey (Jørgensen et al., 2002, 2004), with the outer envelope on scales of 500-5000 AU constrained by detailed line and continuum radiative transfer models.

Fig. 2.1 compares the CO 2–1 (230.5 GHz) and CH\(_3\)OH \(\nu_0 - \nu_0\) \((338.4 \text{ GHz})\) emission for three of the prominent low-mass “hot core” candidates in the NGC 1333 region, NGC 1333-IRAS2A, -IRAS4A and -IRAS4B. Only one of the three (IRAS2A) shows compact CH\(_3\)OH emission as one would expect from a low-mass hot core. The other two in contrast show CH\(_3\)OH emission well separated from the central protostars, likely in shocks where the outflow (traced by the CO lines) impacts the ambient cloud material. Even though analysis of single-dish observations may suggest abundance variations within the envelopes (see discussion in Jørgensen et al. 2005) the SMA observations are crucial to directly image the emission and therefore demonstrate the origin of these abundance enhancements. The shocks traced by the CH\(_3\)OH emission are also found to be coincident with bright 4.5 \(\mu\text{m}\) emission observed by the Infrared Array Camera (IRAC) on the Spitzer Space Telescope. The 4.5 \(\mu\text{m}\) band is particularly sensitive to \(H_2\) rotational lines occurring in shocks where the temperature increases to 500-1000 K. Interestingly, the Spitzer images suggest that the IRAS2A outflow impacts the environment on small scales close to the central protostar in this source. It is therefore likely that the processes regulating the chemistry in IRAS2A are similar to those in the other two protostars: the outflow in this source may simply act on material on much smaller scales than in the two other sources.

This result would be similar to the suggestion for another well-studied low-mass protostellar hot core candidate, IRAS 16293-2422A by Chandler et al. (2005) based on their SMA observations. Chandler et al. showed that a number of high excitation transitions towards this source originate in a shock offset by just a few tenths of an arcsecond \((30-50 \text{ AU})\) from the likely submillimeter continuum driving source.

In summary, direct imaging of the CH\(_3\)OH transitions towards three low-mass hot core candidates with the SMA has shown that CH\(_3\)OH abundance enhancements are likely occurring in shocks associated with the outflows and not necessarily associated with hot cores radiatively heated by the central protostar. A next step in this analysis will be to compare the emission to predictions from the envelope models and to estimate temperatures and densities of the shocks using the available data. We have also obtained

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\(^{1}\)The members of the PROSAC team are Jes Jørgensen, Tyler Bourke, Chin-Fei Lee, Philip Myers, David Wilner, Qizhou Zhang (CfA), James Di Francesco (Herzberg Inst. of Astrophysics, Canada), Nagayoshi Ohashi (ASIAA), Fredrik Schöier (Stockholm Observatory, Sweden), Shigehisa Takakuwa (NAO, Japan) and Ewine van Dishoeck (Leiden Observatory, The Netherlands.)
single-dish maps for the CH$_3$OH and CS emission from the JCMT. An important aspect of the further analysis will be to incorporate these short-spacing data.

**Figure 2.1:** CO and CH$_3$OH emission from SMA observations overlaid on Spitzer images of NGC 1333-IRAS2A (top), NGC 1333-IRAS4A (middle) and NGC 1333-IRAS4B (bottom). In each panel the red and blue contours indicate CO 2–1 emission (red/blue shifted, respectively), the black (top panel) and white (middle/bottom panels) indicate CH$_3$OH $7_0 - 6_0$ emission. The Spitzer images from GTO and c2d observations (Gutermuth et al., in prep.; Jørgensen et al., 2006) show 3.6 $\mu$m emission in blue, 4.5 $\mu$m emission in green and 8.0 $\mu$m emission in red. The beam size of the SMA observations is 1.5–3″; the resolution of the Spitzer images is $\sim 1.2″$.

### References:


**Jes Jørgensen**

### 2.2 Hour-glass magnetic field around NGC 1333 IRAS4A

The polarization of radiation is one of the important signatures of interstellar magnetic fields [1] which are believed to play a critical role in the star formation process [2]. Much information can therefore be obtained by measuring the structure and morphologies of magnetic fields in star forming regions. One of the ways of studying the structure of the plane of the sky component of magnetic fields in the interstellar medium is to observe linearly polarized emission from grains which become aligned perpendicular to the direction of the magnetic field. Such observations need to be made with high angular resolution and good sensitivity. Most of the previous observations of polarized dust emission have been carried out with single dish telescopes such as the JCMT and CSO and with the BIMA and OVRO millimeter arrays. The JCMT observations are quite sensitive to the dust emission, which peaks at submillimeter wavelengths, but lack adequate resolution. Observations made by mm-wave arrays have good angular resolution, but operate at wavelengths where the dust emission is much weaker. The SMA was recently equipped with polarization hardware and it is currently the only interferometer that can conduct observations with adequate sensitivity at high angular resolution [3].

Using the SMA, we have made high angular resolution (1.2″ or 360 AU) measurements of polarized emission at 345 GHz from aligned dust grains towards the Class 0 protostellar binary system NGC 1333 IRAS 4A. The results, which are summarized in Figure 1, clearly show that the magnetic field traces a clear hourglass morphology. Thus, the observed properties of the magnetic field are in agreement with the standard theoretical models of isolated star formation in magnetized molecular clouds in a low-mass star forming region. On larger scales, the polarization direction is quite uniform at a position angle of $\sim 145°$ and is in excellent agreement with earlier lower resolution ob-
servations [5]. The symmetry axis for the magnetic field appears to be approximately perpendicular to the major axis of the extended disk. Using the Chandrasekhar-Fermi method [6], by fitting a set of parabolic curves to the magnetic field lines, we can infer the strength of the magnetic field in the plane of the sky. The resultant intrinsic dispersion in polarization angle is used to obtain the magnetic field strength. We obtain a plane of the sky magnetic field strength of 4 mG. Our analysis reveals that the magnetic field is substantially more important than turbulence in the evolution of the NGC 1333 IRAS4A circumbinary envelope. The magnetic field morphology and the mass-to-magnetic-flux ratio indicate that gravity has overcome magnetic support, as predicted for this stage of star formation. Furthermore, the observed misalignment of the magnetic, outflow and envelope axes might have been an important factor in triggering the observed fragmentation of the core, leading to the formation of a binary system.

We are continuing to use the current polarimetry system to conduct further observations towards other similar objects. An additional set of receivers that will operate over the 330-350 GHz frequency range is currently being installed at the SMA, increasing the sensitivity and simplifying the operation of the polarimetry system. This will allow us to make polarization observations towards a larger sample of YSOs through which we will better understand the role of magnetic fields in the star formation process.

References

R. Rao, D. P. Marrone, J. M. Girart

Figure 2.1: Upper panel: Contour map of the 877 \textmu m dust emission (Stokes I) superposed with the color image of the polarized flux intensity. Red vectors: Length is proportional to fractional polarization and the direction is position angle of linear polarization. Contour levels are 1, 3, 6, 9, 12, 15, 18, 21, 24, 27, 31 \times 65 mJy Beam$^{-1}$. Central panel: Contour and image map of the dust emission. Red bars show the measured magnetic field vectors. Grey bars correspond to the best fit parabolic magnetic field model. Bottom panel: Sketch of the axis directions: red/blue arrows show the direction of the redshifted/blueshifted lobes of the molecular outflow, solid lines show the main axis of the magnetic field, and dashed lines show the envelope axes. The small cross shows the center of the magnetic field symmetry.
3 Engineering Highlights

The next receiver band for the SMA: 320-420 GHz

The receiver lab staff in Cambridge is presently assembling the components of the next receiver band for the SMA. These new receivers will be the fourth set of receivers to be constructed and will cover the 320-420 GHz range. From the point of view of the optics, these receivers will be installed as "high" frequency receivers, and like the 600-695 GHz receivers, they can be used simultaneously with either the 180-245 GHz receivers or the 260-355 GHz receivers. The first two receiver inserts have been fielded on Mauna Kea in antennas 4 and 5 and are currently undergoing commissioning tests. Here we present results from the first fringe test with these receivers, recorded on April 20, 2006. All antennas will have the 320-420 GHz receivers by the end of 2007.

The new receiver band will add several capabilities to the SMA. First, when operated at the same tuning as the 260-355 receivers, they will provide a $\sqrt{2}$ improvement in sensitivity by observing the opposite polarization. Figure 3.1 shows the CO 3-2 line of IRC+10216 recorded in both polarizations simultaneously. The individual spectra are very similar (as expected for an unpolarized source), and the summed spectrum demonstrates the improvement in sensitivity. Once the required modifications to the correlator software have been developed, the SMA will be able to process the cross-polarization products in the correlator, thereby providing full Stokes capability (when the existing quarter waveplates are inserted into the beam).

Alternatively, when the new receivers are operated with a tuning offset from the 260-355 receivers, a wider instantaneous coverage of the submillimeter spectrum can be recorded. For example, with appropriate choice of LO frequencies, four isotopic species of the CO 3-2 line can be observed simultaneously. This capability is demonstrated by the spectra of G5.89-0.39 in Figure 3.2.

Figure 3.1: Simultaneous observations of CO 3-2 and H$_{13}$CN 4-3 lines in IRC+10216 observed in both polarizations (left four panels). The vector averaged spectra (right two panels) with improved S/N. The ordinates are amplitude in Jy (upper) and phase in degrees (lower).
Figure 3.2: Single baseline observations of the high-mass star-forming region G5.89-0.39 with a wide frequency coverage using the 260-355 GHz and 320-420 GHz receivers simultaneously. The lower panels show the simultaneous observations of four isotopes of CO. The middle panel shows the tuning setup and other molecular transitions. The upper panel shows the atmospheric transmission.

Figure 3.3: Simultaneous observations of two different rotational transitions in the same molecule in IRC+10216. The ordinates are amplitude (upper) in Jy and phase (lower) in degrees.

Finally, when operating with the 180-245 GHz receivers, the new receivers will allow the simultaneous observation of two different rotational levels of the same molecule. Figure 3 shows the CS 5-4 and CS 8-7 lines observed simultaneously in IRC+10216. This capability will also provide a sensitive way to test and develop the new calibration method of phase transfer from 230 to 345 GHz. In the past, phase transfer tests have been limited to the 690 band as the high frequency band which can only be attempted in very good weather.

Ken Young & Todd Hunter

19 June 2006
SMA newsletter
4 Proposal Statistics (May - October 2006)

The following tables summarize the proposal statistics for semester 2006-03. The proposals are ranked and grouped into three categories: A (best effort to execute), B (may be executed as conditions permit), and C (will not be executed).

<table>
<thead>
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<th>Category</th>
<th>CfA Pl.</th>
<th>CfA Co.I.</th>
<th>ASIAA</th>
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<td>4A + 5B</td>
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<tr>
<td>690 GHz</td>
<td>42A + 57B</td>
<td>8A + 9B</td>
</tr>
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</table>

The following is the listing of all SAO and ASIAA A-ranked proposals and A & B ranked UH proposals with the names and affiliations of the principal investigators.

**Star Formation**

1. **Sean Andrews (Univ. of Hawaii)**
   2006-03-H01
   The evolution of the gas phase and physical structure of circumstellar disks

2. **Arnold O. Benz (ETH Zurich, Switzerland)**
   2006-03-S048
   Molecules Produced by FUV and X-ray Radiation in AFGL 2591

3. **Tyler Bourke (CfA)**
   2006-03-S032
   Probing the disk of the proto-brown-dwarf-candidate L1014-IRS

4. **Vivien Chen (ASIAA)**
   2006-03-A010
   Resolving the massive protostar IRAS 20126+4104

5. **Claudia Comito (MPIfR, Bonn, Germany)**
   2006-03-S053
   From mm to IR spectroscopy: following up on our pilot study

6. **Michiel R. Hogerheijde (Leiden Observatory, The Netherlands)**
   2006-03-S023
   The CO Disk Around the T Tauri Star IM Lup (Sz 82)

7. **Todd Hunter (CfA)**
   2006-03-S040
   Modeling High Mass Protostellar Objects: Multiplicity and Disks

8. **Jes Jørgensen (CfA)**
   2006-03-S041
   Characterizing young disks: SMA observations of Class I young stellar objects

9. **Eric Keto (CfA)**
   2006-03-S013
   Test for gravitationally dominated hypercompact HII regions

10. **Chin-Fei Lee (CfA)**
    2006-03-S014
    L 1157: A Collimated Outflow With No Apparent Jet?

11. **Brenda Matthews (HIA, Victoria, B.C.)**
    2006-03-S045
    High Resolution Polarized Emission of a Protostellar Core with Unique Polarization Properties

12. **August Muench (CfA)**
    2006-03-S065
    Multiplicity of protostellar and pre-stellar cores associated with the young cluster IC 348.

13. **Phil Myers (CfA)**
    2006-03-S008
    Velocity Structure of the Nearest Cluster-Forming Dense Core

14. **Nagayoshi Ohashi (ASIAA)**
    2006-03-A012
    A detailed study of the peculiar circumstellar disk around HD 142527
15. Nimesh Patel (CfA)  
2006-03-S076  
Imaging the Dust Continuum Emission from Ceph A HW2 at 658 GHz

16. Chunhua Qi (CfA)  
2006-03-S037  
CO J=6-5 Imaging of Protoplanetary Disks

17. Michael Reid (CfA)  
2006-03-S019  
The Structure of a Newly-Discovered Protostellar Outflow in IC 348 SW

18. T. K. Sridharan (CfA)  
2006-03-S049  
Resolving the Binary/Disk System in IRAS20126+4104

19. Ya-Wen Tang (ASIAA)  
2006-03-A013  
Polarization measurement on UCHII region G5.89-0.39

20. Yang Wang (Peking U., P.R. China)  
2006-03-S020  
The Clump Mass Function of a Pre-protocluster

21. Jonathan Williams (Univ. of Hawaii)  
2006-03-H23  
Star-formation in photoionized regions

22. Elaine Winston (CfA)  
2006-03-S071  
The Evolution of Disks and Envelopes in the Serpens Embedded Cluster

23. Luis Zapata (CfA)  
2006-03-S018  
Tracing the Origin of the Quadrupolar Outflows

24. Richard C.Y. Chou (ASIAA)  
2006-03-A007  
Circumnuclear disk or starburst ring in the nearby Seyfert galaxy NGC 4945?

25. Len Cowie (Univ. of Hawaii)  
2006-03-H38

26. Melanie Krips (CfA)  
2006-03-S015  
Does HCN distinguish between starburst and pure AGN? Mapping the HCN(3-2) emission in M82, NGC6240 & NGC6951

27. Satoki Matsushita (ASIAA)  
2006-03-A004  
NGC 7552: Star formation in a barred, ringed galaxy

28. Glenn Morrison (Univ. of Hawaii)  
2006-03-H41  
Imaging cold dust reservoirs in massive radio galaxies at high-redshift

29. Glen Petitpas (CfA)  
2006-03-S044  
SCONES: Determining the Warm Gas Properties of Nearby Galaxies

30. Kazushi Sakamoto (NAOJ, Tokyo, Japan)  
2006-03-S026  
Resolving the Hearts of Two Local Starbursts

Stellar

31. V. Bujarrabal (OAN, Alcala de Menares, Spain)  
2006-03-S004  
The Rotating Disk in the Protoplanetary Nebula IRAS 18059-3211

32. Meredith Hughes (Harvard University)  
2006-03-S034  
The Transition Disk around 49 Ceti

33. David Wilner (CfA)  
2006-03-S025  
High Resolution Survey of Taurus Protoplanetary Disks

Extragalactic

34. Mark A. Gurwell (CfA)  
2006-03-S001  
Imaging Io
Galactic Center

36. Ray Blundell (CfA)
2006-03-S080
The Ionized ISM in The Central Parsec of The Galaxy

37. Maria Montero-Castano (CfA)
2006-03-S066
Mapping the CND with high-density tracers

Other

38. Jonathan Weintroub (CfA)
2006-03-S060
High frequency imaging of the RRL masers in MWC349A

5 Recent SMA publications

The high-mass star-forming region IRAS18182-1433
(1) MPIA, (2) CfA
Submillimeter Array 1.3 mm line and continuum observations toward the young massive star-forming region IRAS18182-1433 are presented. The data are complemented with short-spacing CO (2-1) observations and SiO (1-0) data from the VLA. Multiple massive outflows emanate from the mm continuum peak. The CO (2-1) data reveal a quadrupolar outflow system consisting of two outflows inclined by $\sim 90^\circ$. One outflow exhibits a cone-like red-shifted morphology with a jet-like blue-shifted counterpart where a blue counter-cone can only be tentatively identified. The SiO (1-0) data suggest the presence of a third outflow. Analyzing the $^{12}$CO/$^{13}$CO line ratios indicates decreasing CO line opacities with increasing velocities. The other seven detected molecular species - also high-density tracers like CH$_3$CN, CH$_3$OH, HCOOCH$_3$ - are all $\sim 1 - 2''$ offset from the mm continuum peak, but spatially associated with a strong molecular outflow peak and a cm emission feature indicative of a thermal jet. This spatial displacement between the molecular lines and the mm continuum emission could be either due to an unresolved sub-source at the position of the cm feature, or the outflow/jet itself alters the chemistry of the core enhancing the molecular abundances toward that region. A temperature estimate based on the CH$_3$CN(12$\nu$-11$\nu$) lines suggests temperatures of the order 150K. A velocity analysis of the high-density tracing molecules reveals that at the given spatial resolution none of them shows any coherent velocity structure which would be consistent with a rotating disk. We discuss this lack of rotation signatures and attribute it to intrinsic difficulties to observationally isolate massive accretion disks from the surrounding dense gas envelopes and the molecular outflows.

Accepted for publication in A&A (astro-ph/06003814)

The flare activity of Sgr A* 

We report new simultaneous near-infrared/submillimeter/X-ray observations of the SgrA* counterpart associated with the massive $3-4\times10^6$ M$_\odot$ black hole at the Galactic Center. The main aim is to investigate the physical processes responsible for the variable emission from SgrA*. The observations have been carried out using the NACO adaptive optics (AO) instrument at the European Southern Observatory’s Very Large Telescope and the ACIS-I instrument aboard the Chandra X-ray Observatory as well as the Submillimeter Array SMA on Mauna Kea, Hawaii, and the Very Large Array in New Mexico. We detected one moderately bright flare event in the X-ray domain and 5 events at infrared wavelengths.


Millimeter Multiplicity in NGC 6334 I and I(N)
T.R. Hunter1, C.L. Brogan2, S.T. Megeath1,3, K.M. Menten4, H. Beuther5, S. Thorwirth1
(1) CfA, (2) NRAO, (3) Univ. of Toledo, (4) MPIfR, (5) MPIA

Using the Submillimeter Array (SMA), we have imaged the 1.3 millimeter continuum emission at the center of the massive star-forming regions NGC 6334 I and I(N). In both regions, the SMA observations resolve the emission into multiple millimeter sources, with most of the sources clustered into areas only 10,000 AU in diameter. Toward NGC 6334 I, we find four compact sources: the two brightest (I-SMA1 and I-SMA2) are associated with previously-known ammonia cores; I-SMA3 is coincident with the peak
A Detection of [C II] Line Emission in the z = 4.7 QSO BR1202-0725

Daisuke Iono1,2, Min S. Yun3, Martin Elvis3, Alison B. Peck2, Paul T. P. Ho2,4, David J. Wilner2, Todd R. Hunter2, Satoki Matsushita1, Sebastien Muller4
(1) NAOJ, (2) CfA, (3) Univ. of Massachusetts, Amherst, (4) ASIAA

We present ∼ 3\arcsec resolution imaging of the z = 4.7 QSO BR1202-0725 at 900 \micron from the Submillimeter Array. The two submillimeter continuum components are clearly resolved from each other, and the positions are consistent with previous lower frequency images. In addition, we detect [C II] line emission from the northern component. The ratio of [C II] to far-infrared luminosity is 0.04% for the northern component, and an upper limit of < 0.03% is obtained for the southern component. These ratios are similar to the low values found in local ultraluminous galaxies, indicating that the excitation conditions are different from those found in local field galaxies. X-ray emission is detected by Chandra from the southern component at L_{0.5-2keV} = 3 \times 10^{45} \text{ erg s}^{-1}, and detected at 99.6% confidence from the northern component at L_{0.5-2keV} \sim 3 \times 10^{44} \text{ erg s}^{-1}, supporting the idea that BR1202-0725 is a pair of interacting galaxies at z = 4.7 that each harbor an active nucleus.

Accepted for publication in ApJ (astro-ph/0606043)

Interferometric 890 micron images of high redshift submillimeter galaxies

D. Iono1,2, A. B. Peck3, A. Pope3, C. Borys3, D. Scott3, D. J. Wilner1, M. Gurwell1, P. T. P. Ho1, M. S. Yun5, S. Matsushita6, G. R. Pettipas1, J. S. Dunlop7, M. Elvis1, A. Blain4, E. Le Floc'h8
(1) CfA, (2) NAOJ, (3) UBC, (4) Caltech, (5) UMass, (6) ASIAA, (7) Univ. of Edinburgh (8) Univ. of Arizona

We present high resolution 890 \micron images of two 20

Adapting and expanding interferometric arrays

A. Karastergiou1, R. Neri1, M. A. Gurwell2
(1) IRAM, (2) CfA

We outline here a simple yet efficient method for finding optimized configurations of the elements of radio-astronomical interferometers with fixed pad locations. The method can be successfully applied, as we demonstrate, to define new configurations when changes to the array take place. This may include the addition of new pads or new antennas, or the loss of pads or antennas. Our method is based on identifying which placement of elements provides the most appropriate uv plane sampling for astronomical imaging.

Accepted for publication in ApJS (astro-ph/0602578)

The Spitzer C2D Survey of Nearby Dense Cores: III: Low Mass Star Formation in a Small Group L1251B

Jeong-Eun Lee1,5, James Di Francesco2, Shih-Ping Lai3,8,9, Tyler L. Bourke4, Neal J. Evans II3, Bill Spiesman5, Philip C. Myers4, Lori E. Allen4, Timothy Y. Brooke6, Alicia Porras4, Zahed Wahhaj7
(1) Hubble Fellow, UCLA, (2) Herzberg Institute of Astrophysics, (3) Univ. of Maryland, (4) CfA, (5) Univ. of Texas, (6) Caltech, (7) Northern Arizona Univ., (8) National Tsing Hua Univ., (9) ASIAA

We present a comprehensive study of a low-mass star-forming region, L1251B, at wavelengths from the near-infrared to the millimeter. L1251B, where only one protostar, IRAS 22376+7455, was known previously, is confirmed to be a small group of protostars based on observations with the Spitzer Space Telescope. The most luminous source of L1251B is located 5\arcsec north of the IRAS position. A near-infrared bipolar nebula, which is not associated with the brightest object and is located at the southeast corner of L1251B, has been detected in the IRAC bands. OVRO and SMA interferometric observations indicate that mJy submillimeter galaxies, SMMJ123711+622212 and MIPS J142824.0+352619, obtained using the Submillimeter Array (SMA). Using submillimeter interferometric observations with an angular resolution of 2\arcsec, the coordinates of these high redshift sources are determined with an accuracy of 0.2\arcsec. The new SMA data on SMMJ123711+622212 reveal an unresolved submm source offset to the east by 0.7\arcsec from an optical galaxy found in deep HST images, suggesting either a large galaxy with a dusty central region, or an interacting galaxy system. The SMA image of hyper-luminous (LFIR = 3.2 x 10^{13} L_{\odot}) source MIPS J142824.0+352619 provides a firm upper limit to the source size of < 1\arcsec.2. This constraint provides evidence that the foreground lens is only weakly affecting the observed high FIR luminosity.

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the brightest source and the bipolar nebula source in the IRAC bands are deeply embedded disk sources. Submillimeter continuum observations with single-dish telescopes and the SMA interferometric observations suggest two possible prestellar objects with very high column densities. Outside of the small group, many young stellar object candidates have been detected over a larger region of 12′ x 12′. Extended emission to the east of L1251B has been detected at 850 μm; this “east core” may be a site for future star formation since no point source has been detected with IRAC or MIPS. This region is therefore a possible example of low-mass cluster formation, where a small group of pre- and protostellar objects (L1251B) is currently forming, alongside a large starless core (the east core).

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### POSSIBLE MOLECULAR SPIRAL ARMS IN THE PROTOPLANETARY DISK OF AB AUR

Shin-Yi Lin\(^1\), Nagayoshi Ohashi\(^1\), Jeremy Lim\(^1\), Paul T.P Ho\(^{1,2}\), Misato Fukagawa\(^3\), Motohide Tamura\(^3\)

\(^{(1)}\) ASIAA, (2) CfA, (3) NAOJ

The circumstellar dust disk of the Herbig Ae star AB Aur has been found to exhibit complex spiral-like structures in the near-IR image obtained with the Subaru Telescope. We present maps of the disk in both \(^{12}\)CO (3-2) and dust continuum at 345 GHz with the SMA at an angular resolution of 1.3'' x 0.87'' (144 AU x 100 AU). The continuum emission traces a dust disk with a central depression and a maximum overall dimension of 450 AU (FWHM). This dust disk exhibits several distinct peaks that appear to coincide with bright features in the near-IR image, in particular the brightest inner spiral arm. The CO emission traces a rotating gas disk of size 530 AU x 330 AU with a deprojected maximum velocity of 2.8 km/s at 450 AU. In contrast to the dust disk, the gas disk exhibits an intensity peak at the stellar position. Furthermore, the CO emission in several velocity channels traces the innermost spiral arm seen in the near-IR. We compare the observed spatial-kinematic structure of the CO emission to a simple model of a disk in Keplerian rotation, and find that only the emission tracing the main spiral arm clearly lies outside the confines of our model. This emission has a net outward radial motion compared with the radial velocity predicted by the model at the location of the main spiral arms. The disk of AB Aur is therefore quite different from the Keplerian disks seen around many Herbig Ae stars. The spiral-like structures of the disk with non-Keplerian motions we revealed in \(^{12}\)CO (3-2), together with the central depression of the dust disk, may be explained to be driven by the possible existence of a giant planet forming in the disk.

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### A KEPLERIAN DISK AROUND THE HERBIG AE STAR HD169142

A. Raman\(^1\), M. Lisanti\(^{1,2}\), D.J. Wilner\(^1\), C. Qi\(^1\), M. Hogerheijde\(^3\)

\(^{(1)}\) CfA (2) Stanford University, (3) Leiden Observatory

We present Submillimeter Array observations of the Herbig Ae star HD169142 in 1.3 millimeter continuum emission and \(^{12}\)CO J=2-1 line emission at 1.5 arcsecond resolution that reveal a circumstellar disk. The continuum emission is centered on the star position and resolved, and provides a mass estimate of about 0.02 solar masses for the disk. The CO images show patterns in position and velocity that are well matched by a disk in Keplerian rotation with low inclination to the line-of-sight. We use radiative transfer calculations based on a flared, passive disk model to constrain the disk parameters by comparison to the spectral line emission. The derived disk radius is 235 AU, and the inclination is 13 degrees. The model also necessitates modest depletion of the CO molecules, similar to that found in Keplerian disks around T Tauri stars.

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### IMAGING MOLECULAR GAS IN THE LUMINOUS MERGER NGC 3256: DETECTION OF HIGH VELOCITY GAS AND TWIN GAS PEAKS IN THE DOUBLE NUCLEUS

Kazushi Sakamoto\(^{1,2}\), Paul T. P. Ho\(^{1,3}\), Alison B. Peck\(^1\)

\(^{(1)}\) CfA, (2) NAOJ, (3) ASIAA

Molecular gas in the merging starburst galaxy NGC 3256 has been imaged with the Submillimeter Array at a resolution of 1'' x 2'' (170 x 4 340 pc at 35 Mpc). This is the first interferometric imaging of molecular gas in the most luminous galaxy within z = 0.01. There is a large disk of molecular gas (r > 3 kpc) in the center of the merger with a strong gas concentration toward the double nucleus. The gas disk having a mass of \(\sim 3 \times 10^9 M_\odot\) in the central 3 kpc rotates around a point between the two nuclei that are 850 pc apart on the sky. The molecular gas is warm and turbulent and shows spatial variation of the intensity ratio between CO isotopomers. High-velocity molecular gas is discovered at the galactic center. Its velocity in our line of sight is up to 420 km/s offset from the systemic velocity of the galaxy; the terminal velocity is twice as large as that due to the rotation of the main gas disk. The high-velocity gas is most likely due to a molecular outflow from the gas disk, entrained by the starburst-driven superwind in the galaxy. The molecular outflow is estimated to have a rate of \(\sim 10 M_\odot/yr\) and to play a significant role in the dispersal or depletion of molecular gas from the galactic center. A compact gas concentration and steep velocity gradient are also found around each of the twin nuclei. They are suggestive of a small gas disk rotating around each nucleus. If these are indeed mini-disks, their dynamical masses are \(\sim 10^6 M_\odot\) within a radius of 170 pc.

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The distribution of SiO in the circumstellar envelope around IRC+10216

F. L. Schoier\textsuperscript{1}, D. Fong\textsuperscript{2}, H. Olofsson\textsuperscript{2}, Q. Zhang\textsuperscript{2}, N. A. Patel\textsuperscript{2}

\textsuperscript{(1) Stockholm Observatory, (2) CfA}

New interferometric observations of SiO $J = 5 - 4$ circumstellar line emission around the carbon star IRC+10216, using the Submillimeter Array, are presented. Complemented by multi-transition single-dish observations, including infrared observations of ro-vibrational transitions, detailed radiative transfer modeling suggests that the fractional abundance of SiO in the inner part of the envelope, between $\approx 3 - 8$ stellar radii, is as high as $\approx 1.5 \times 10^{-6}$. This is more than an order of magnitude higher than predicted by equilibrium stellar atmosphere chemistry in a carbon-rich environment and indicative of the importance of non-LTE chemical processes. In addition to the compact component, a spatially more extended ($r_c \approx 2.4 \times 10^{16}$ cm) low-fractional-abundance ($f_0 \approx 1.7 \times 10^{-7}$) region is required to fit the observations. This suggests that the majority of the SiO molecules are effectively accreted onto dust grains in the inner wind while the remaining gas-phase molecules are eventually photodissociated at larger distances. Evidence of departure from a smooth wind is found in the observed visibilities, indicative of density variations of a factor 2 to 5 on an angular scale corresponding to a time scale of about 200 years. Additionally, constraints on the velocity structure of the wind are obtained.

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