SMA Newsletter

Submillimeter Array Newsletter | Number 22 | July 2016

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FROM THE DIRECTOR

Dear SMA Newsletter readers,

I am happy to announce that our ongoing instrument upgrade program has reached a significant milestone; specifically that the SWARM correlator is now running at full speed. With two SWARM quadrants in operation, this enables 16 GHz on-sky bandwidth to be processed simultaneously from either a single receiver (4 – 12 GHz IF, 2 sidebands) or from two receivers in dual-receiver mode (6 – 10 GHz IF, 2 sidebands, and 2 receivers). We are currently assembling the third quadrant of SWARM, which we plan to commission before the start of the next observing semester, 2016B, November 16th. While this third quadrant will not increase the throughput of the SMA for single receiver operation, it will enable 24 GHz of on-sky bandwidth to be processed simultaneously in dual-receiver mode (4 – 10 GHz IF, 2 sidebands, and 2 receivers), and will naturally result in a change to a default observing strategy that makes use of dual-receiver operation for all SMA observations.

Along with the increased correlator capacity, we will also offer the standard 230 GHz, 345 GHz and wide-banded 400 GHz receivers, each with IFs from 4 – 12 GHz, and the new 240 GHz receivers. Together these will enable dual-frequency operation combining a 230 GHz or 240 GHz receiver with the 345 GHz or 400 GHz receiver; or dual-frequency (or dual-polarization) operation with either the 230 and 240 GHz receiver sets, or the 345 and 400 GHz receiver sets.

Furthermore, since we expect to build, install, and commission the fourth quadrant of SWARM by the end of this calendar year, which will offer 32 GHz on-sky bandwidth (16 GHz per receiver), most SMA data sets will be significantly larger, than current data sets, with up to 300 GB per track at full resolution. In the upcoming call for observing proposals, we are therefore offering PIs the option of accessing their data at reduced spectral resolution. In addition, while we are not a service organization, we will provide PIs with a sample data reduction of their observations upon request (**SMAdataSample@cfa.harvard.edu**).

As our near-term upgrades progress, we are continuing to develop plans for significant, long-term instrument upgrades to the SMA. These will be discussed in a workshop to be held in October (SMA Science in the Next Decade; see the announcement on **page 14**), and at the next SMA governing board meeting later in the year.

Ray Blundell

A HIGH-MASS PROTOSTAR FED BY A HOT AND MASSIVE DISK

Huei-Ru Vivien Chen (NTHU), Eric Keto (CfA), Qizhou Zhang (CfA), T. K. Sridharan (CfA), Sheng-Yuan Liu (ASIAA), Yu-Nung Su (ASIAA)

What role accretion disks play in the formation of high-mass stars ($M \gtrsim 8 M_{\odot}$) remains a long-standing question. Circumstellar disks form naturally in the centers of rotating inflows and are a key element in the standard paradigm of the formation of Sun-like stars, providing for the growth of planetary systems. However, it remains debatable whether high-mass stars form in a similar fashion. On theoretical grounds, a very high accretion rate ($\gtrsim 10^{-4}\ M_{\odot}\ \mathrm{yr}^{-1}$) is required to form stars more massive than 8 $M_{\odot}$. Stars this massive undergo rapid enough Kelvin-Helmholtz contraction that they begin hydrogen burning while still accreting (1). A continuous resupply of fresh hydrogen is required to allow a growing massive protostar to reach the mass of a B or O star before exhausting its hydrogen fuel and leaving the main sequence (2). Such rapid accretion could induce gravitational instabilities in the accretion flow that would make the disk prone to fragmentation, perhaps producing companion objects (3).

The few observations reporting disk-like accretion flows around high-mass protostars (4-8) have not had the spectral and spatial resolution to determine the stability of the candidate disks, which

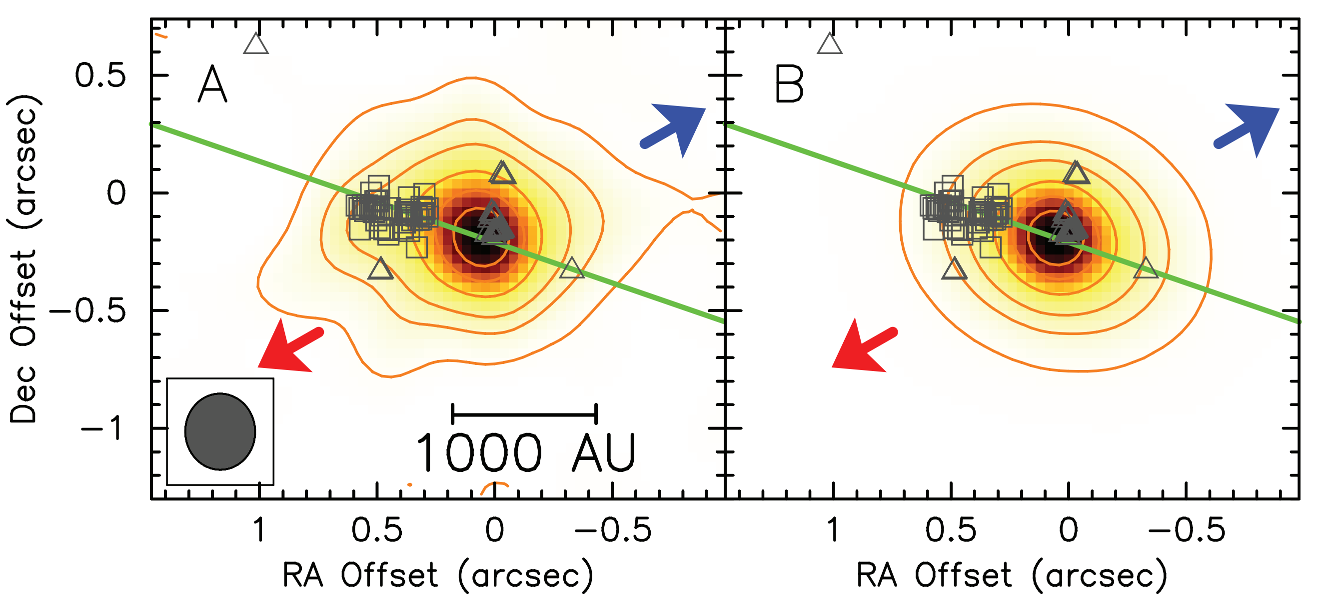

Figure 1: 870 μm observation and model images of dust emission. (A) Continuum map of IRAS 20126+4104. The green line at P.A. of 70° shows the disk plane in our optimized model. Arrows indicate the direction of the bipolar molecular outflow. Triangles and squares are the positions of H_2O and CH_3OH masers, respectively. (B) Synthetic image of the optimized model for dust emission.

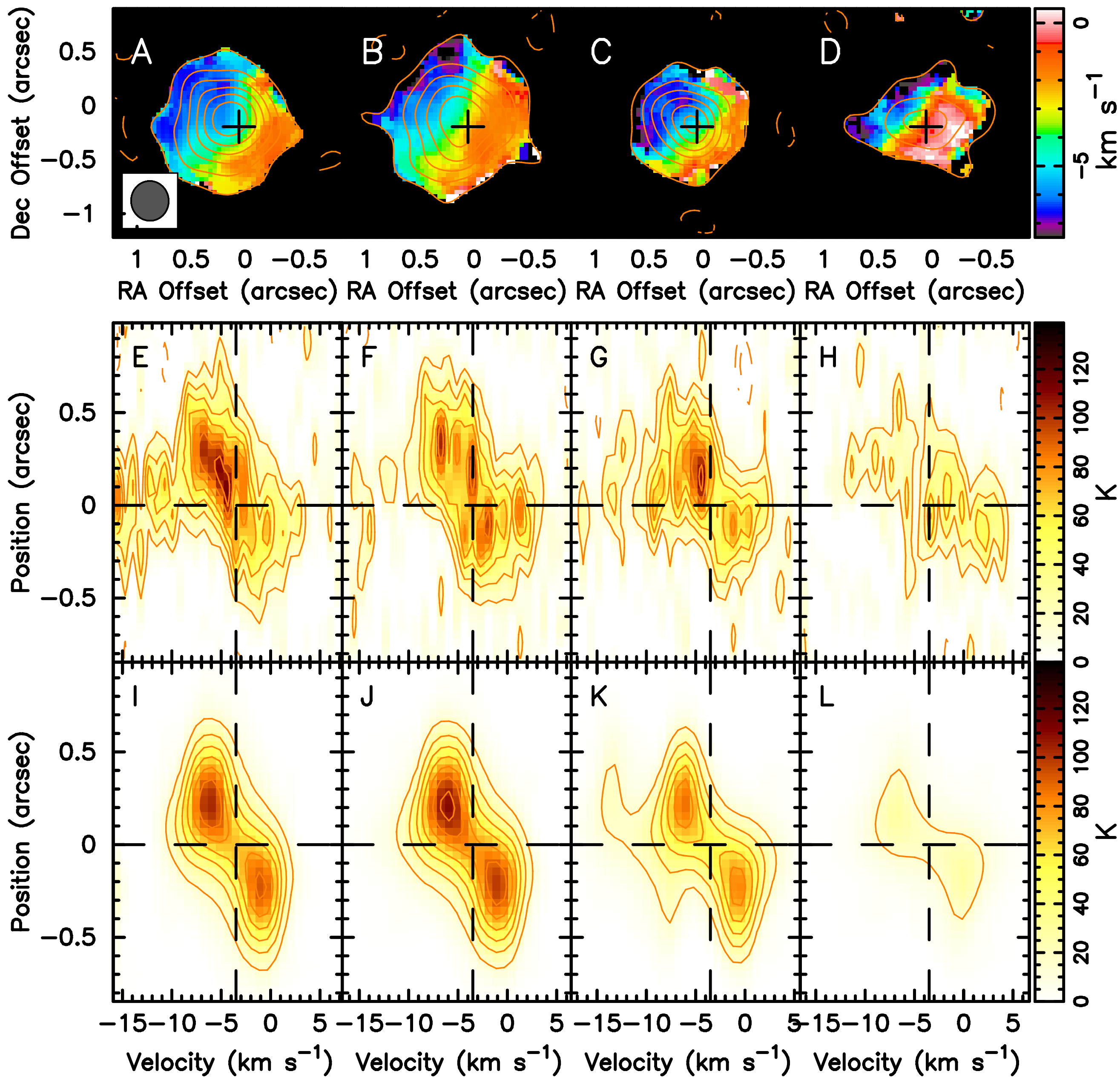

Figure 2: Results of line observations and models. (A-D) Integrated intensity map (contours) overlaid on intensity-weighted velocity map (color) of the $K = 2,3,6,9$ components of the CH_3CN $J = 19$-18 transition, whose upper states have increasing energies of $E_{up} = 196,232,425,745$ K and are expected to trace emission progressively close to the hot protostar. The cross marks the position of the continuum peak. **(E-H)** Position-velocity diagram of **A-D** through the disk plane (P.A. = 70°). Vertical dashed line gives the systemic velocity of -3.5km/s^{-1}. **(I-L)** Position-velocity diagram of the synthetic line image cube corresponding to E-H..

may be assessed by the Toomre-Q parameter. The Toomre-Q summarizes the competing effects of the forces affecting the dynamical stability of the accretion flow: the differential shear in the rotating disk and the gas temperature together stabilize the disk against the clumping tendency of the self-gravity of the disk surface density. Values of Q>1 imply a stable disk.

We conducted spectral line observations of multiple K components of the CH_3CN $J = 19$-18 transition in the accretion disk around the massive protostar IRAS 20126+4104. For the first time, we measure the disk density, temperature, and rotational velocity with sufficient resolution (0.37″, equivalent to 600 au) to assess the gravitational stability of the disk (9). Our observations resolve the central 2000 au region that shows steeper velocity gradients with increasing upper state energy, indicating an increase in the rotational velocity of the hotter gas nearer the star (**Fig. 1A and Fig. 2A-2H**). Such spin-up motions are characteristics of an accretion flow in a rotationally supported disk.

We can extract precise measurements of the disk and envelope temperatures, densities, and velocities by comparing the observations with model accretion flows. Following earlier studies (10, 11) that modeled lower angular resolution observations, we constructed a 3-D analytical model describing a thin accretion disk (12) in Keplerian motion enveloped within the centrifugal radius of an angular-momentum-conserving accretion flow (13). We include stellar irradiation to heat the flared disk (14) consistent with the presence of outflow cavities (15). Under conditions of LTE, we solved the radiative transfer equations for the intensity of the continuum and spectral lines simultaneously to construct synthetic continuum images and spectral image cube for comparison with the observations (**Fig. 1B and Fig. 2I-2L**).

In contrast to some theoretical expectations of massive disks prone to local instabilities, we find that the disk of IRAS 20126+4104 is hot and stable to fragmentation with $Q > 2.8$ at all radii (**Fig. 3**), which permits a smooth accretion flow even as the accretion proceeds at a high rate (9). Such conditions may help to maintain the disk around massive stars and preserve opportunities for developing companions or a planetary system in a later phase of the protostellar evolution.

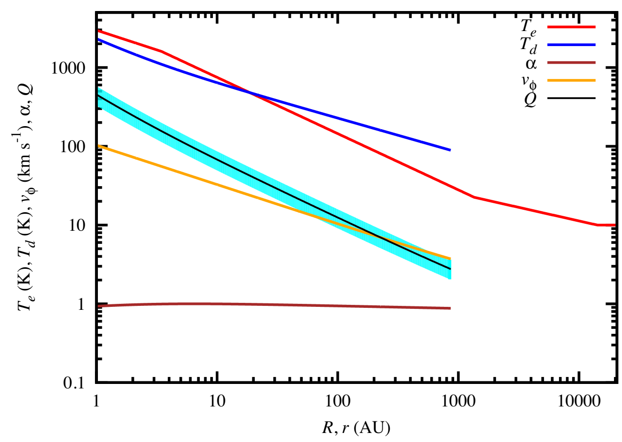

Figure 3: Parameters in the optimized model vs. radius, including the envelope temperature, T_e (red), the disk temperature, T_d (blue), the rotational velocity in the disk, v_ϕ (orange), the Shakura-Sunyaev α parameter (brown), and the Toomre-*Q* (black) with uncertainty range (cyan). The Toomre-*Q* is everywhere larger than 2.8, which makes the disk stable to gravitational instability.

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RESOLVING ORDERED MAGNETIC FIELDS NEAR THE EVENT HORIZON OF A SUPERMASSIVE BLACK HOLE

Michael D. Johnson (CfA), on behalf of the Event Horizon Telescope

Magnetic fields in the immediate vicinity of a black hole are central to many major theoretical ideas in astrophysics. For example, magnetic fields are thought to drive turbulence in an accretion disk via the magnetorotational instability (MRI), producing the necessary viscosity for efficient accretion (Balbus & Hawley 1991), and they can thread a rotating accretion disk, driving outflows centrifugally (Blandford & Payne 1982). They can even pierce the event horizon of a spinning black hole, extracting rotational energy from the black hole itself and accelerating matter into jets (Blandford & Znajek 1977). Yet, despite their fundamental role in the accretion, emission, and outflow of galactic nuclei, current theories of magnetic fields near a black hole have not been constrained on event horizon scales.

The most promising target to study these magnetic fields directly is our Galactic Center supermassive black hole, Sagittarius A* (Sgr A*). Sgr A* has a mass of approximately 4.3×10^6 $M_\odot$ and lies at a distance of ~8 kpc, so its Schwarzschild radius ($R_{Sch} = 2GM/c^2$) is 0.1 AU and subtends 10 μas (Ghez et al. 2008, Gillessen et al. 2009). Sgr A* emits brightly in synchrotron radiation at submillimeter wavelengths, and this emission is expected to be highly polarized with its direction tracing the local magnetic field direction. The SMA has already provided critical information about the polarization of Sgr A*, measuring its 5-10% fractional linear polarization at 230 and 345 GHz, its Faraday rotation measure, and its circular polarization (Marrone et al. 2006, 2007; Munoz et al. 2012). The SMA has even observed intra-hour variability in the polarization fraction (Marrone et al. 2006b). However, these observations have not resolved the compact emission region. And because of hyper-strong scattering in the ionized interstellar medium along the line of sight to the Galactic Center, observations must be performed at wavelengths of only a few millimeters or shorter to detect the intrinsic structure of Sgr A*. Consequently, facility instruments such as the VLBA cannot be used to study this structure.

To address these challenges, we have been developing the Event Horizon Telescope (EHT), a global very long baseline interferometry (VLBI) array operating at 1.3-mm wavelength. The EHT links premier submillimeter facilities, including the SMA, to create an Earth-sized telescope with an angular resolution of approximately 20 microarcseconds (μas). The SMA has participated in EHT campaigns since 2007. These observations have demonstrated that the submillimeter emission from Sgr A* arises from a region that subtends only ~4 R_{Sch} (Doeleman et al. 2008, Fish et al. 2011). In

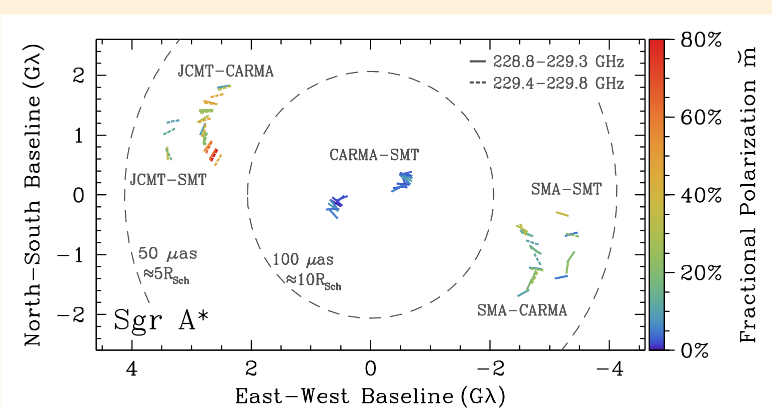

Figure 1: Interferometric fractional polarization measurements for Sgr A*. The color and direction of the ticks indicate the amplitude and direction of the linear polarization, respectively. The fractional polarization is expected to change smoothly as the baseline orientation changes with the rotation of the Earth, and the polarization of Sgr A* is also highly variable in time. The difference between the polarization on baselines to the JCMT (which recorded right circular polarization) and baselines to the SMA (which recorded left circular polarization) indicates variation in the polarization direction throughout the emission region.

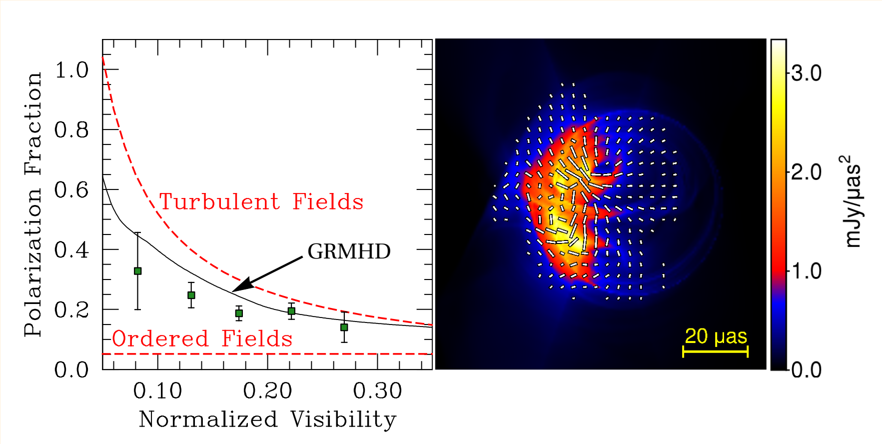

Figure 2: Strength and order of the polarization field from 1.3-mm VLBI. Points with errors (±1σ) in the left panel show the average of binned EHT polarization measurements. Dashed orange lines show two limiting cases: a uniform polarization field and a highly disordered (unresolved) polarization field. The EHT measurements identify a mix of ordered and tangled fields that is compatible with the GRMHD simulation shown on the right.

March 2013, the EHT observed Sgr A* for five nights using sites in California, Arizona, and Hawaii. In California, we phased together eight antennas from CARMA, and in Arizona, we used the 10-m SMT. In Hawaii, seven 6-m dishes of the SMA were combined into a single-polarization phased array, while the JCMT recorded the opposite polarization, forming a single effective dual-polarization station. We recorded two 512 MHz bands, centered on 229.089 GHz and 229.601 GHz, and circular polarizations.

These data revealed polarized structures in Sgr A* on ~6 R_{Sch} scales (**Fig. 1**). The high (up to ~70%) and smoothly varying polarization fractions were an order of magnitude larger than those seen on shorter baselines, showing that we are resolving ordered magnetic fields on event-horizon scales near the black hole (**Fig. 2**). Measurements on shorter baselines showed variations that are tightly correlated with those seen in simultaneous connected-element measurements, reflecting intra-hour intrinsic variability associated with compact structures near the black hole. These observations were the first polarimetric VLBI ever achieved at 1.3mm wavelength and the first observations to resolve the polarized emission of Sgr A* at any wavelength.

In an environment of turbulent accretion and magnetically driven instabilities, several effects can produce ordered fields near the event horizon. For example, as the orbits of the accreting material around the black hole become circular, magnetic fields will be azimuthally sheared by the differential rotation, resulting in a predominantly toroidal configuration (Hirose et al. 2004). Alternatively, accumulation of sufficient magnetic flux near the event horizon may have led to a stable, magnetically dominated inner region, suppressing the disk rotation and the MRI (Narayan et al. 2003). Emission from a magnetically dominant region also provides an attractive explanation for the long-term stability of the circular polarization handedness and the linear polarization direction of Sgr A* (Bower et al. 2002). As **Fig. 2** shows, the relative balance between order and disorder in the polarization field is compatible with current general relativistic magnetohydrodynamic (GRMHD) simulations of magnetically arrested disks (Gold et al. 2016).

With the advent of polarimetric VLBI with the EHT, we are now resolving the magnetized core of our Galaxy's central engine. These measurements provide direct evidence of ordered magnetic fields near Sgr A*, firmly grounding decades of theoretical work. In the next few years, the EHT will expand from three geographical locations to seven, will extend the recorded bandwidth by a factor of 16, and will natively be full-polarization by using the new SMA dual-polarization receivers. These developments will soon enable imaging of these magnetic structures and variability studies on the 20-second gravitational timescale (GM/c^3) of Sgr A* (Chael et al. 2016).

For more information, please refer to Johnson, M. D., Fish, V. L., Doeleman, S. S., et al. 2015, Science, 350, 1242.

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RESOLVED CO GAS INTERIOR TO THE DUST RINGS OF THE HD 141569 DISK

K. Flaherty, A.M. Hughes, S.M. Andrews, C. Qi, D.J.Wilner, A. Boley, J.A. White, W. Harney, J. Zachary

Debris disks are characterized by second generation dust produced from the collisional grinding of planetesimals. Most observations focus on the scattered light and thermal emission from the dust, but the presence of gas can substantially influence the observed dust structures (Takeuchi & Artymowicz 2001; Lyra & Kuchner 2013). While surveys have found that most debris disks have a negligible gas mass, some systems possess significant molecular line emission in the (sub)mm (Hughes et al. 2008, Kóspál et al. 2013, Moór et al. 2015, Marino et al. 2016, Lieman-Sifry et al. 2016).

One of the first debris disks discovered to have a significant gas reservoir is hosted by the 5 Myr old A star HD 141569 (Zuckerman et al. 1995). Early scattered light images found small dust grains confined to two narrow rings at ~250 and ~400 au (Weinberger et al. 1999). Owing in larger part to advances in high-resolution, high-contrast imaging, HD 141569 has received renewed interest in the past year revealing additional complex structure within 200 au (Biller et al. 2015, Mazoyer et al. 2016, Currie et al. 2016, Perrot et al. 2016, Konishi et al. 2016). The origin of such structures depends in part on the gas. Cospatial gas and dust can lead to sharp rings without the need for shepherding planets (Lyra & Kuchner 2013), while collisions with gas as dust grains are pushed outwards by radiation pressure can lead to a ring at the outer edge of the gaseous disk (Takeuchi & Artymowicz 2001).

To understand the spatial distribution of the gas, we obtained ~arcsecond resolution observations of CO(3-2) with the SMA (**Figure 1**). The images clearly show the CO gas confined to the area within the outer scattered light rings originally observed by Weinberger et al. (1999). Fitting these data, along with complementary CARMA CO(1-0) observations, we find that the disk stretches from $29\pm^{14}_{20}$ au out to $204\pm^{19}_{18}$ au with a mass of $13\pm^{50}_{9}$ $M_{\oplus}$. ALMA CO(3-2) observations find a similar gas structure (White et al. 2016).

Our finding of CO gas confined to radii smaller than that of the scattered light rings has important implications for the origin of the small dust grains. In an optically thin disk, grains experience an outward force due to radiation pressure, which can often overwhelm the gravitational pull of the central star. Sub-micron sized grains are quickly blown out of the system on dynamical timescales, while larger grains settle into orbits at slightly sub-Keplerian velocities. For the larger grains, the presence of gas can further affect these orbits. If the radiation pressure influenced orbit is such that the grains move slower than the gas then the grains will experience a tailwind which increases their angular momentum. These grains will move outward until they reach the outer edge of the gas disk, similar to what is seen in the HD 141569 system. This scenario does rely on small dust grains being generated in

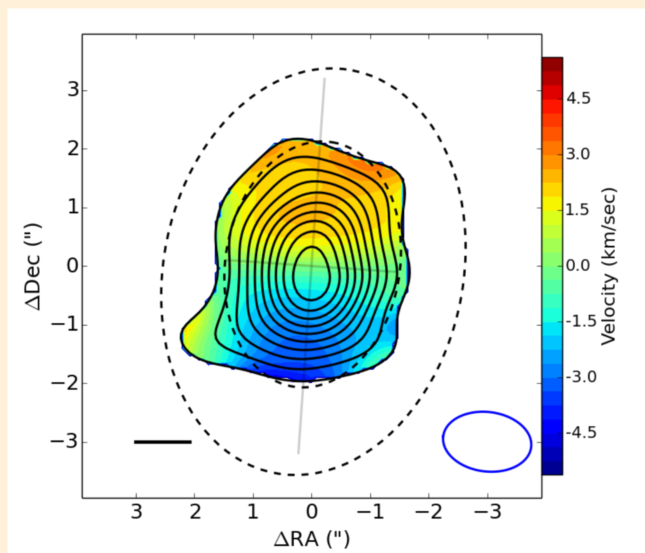

Figure 1: CO(3-2) moments zero (total intensity, black contours) and one (intensity-weighted velocity, filled contours). Intensity contours are in units of 3σ, 5σ, 7σ, … (σ=0.24 Jy/beam), the black horizontal line marks a distance of 100 au, and the circle in the lower right indicates the beam size. The two dashed circles mark the location of the two outer rings seen in the scattered light. The CO gas is not cospatial with the small dust grains but is instead located within the inner disk

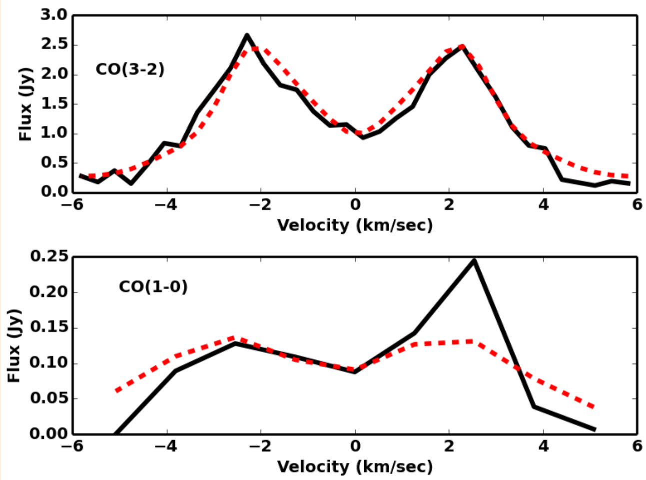

Figure 2: Spectra derived from images within a 10" box for CO(3-2) (top panel) and CO(1-0) (bottom panel). Data are shown with the solid black lines, while the model spectra are shown with red dashed lines. To match the relative line flux of these two lines, a low excitation temperature is needed, indicative of substantial gas cooling or significant NLTE effects.

the inner disk, and the recent high-resolution dust observations have started to reveal the structure within this region. The outermost ring may result from the close passage between one of the close companions and the disk (Clampin et al. 2003).

Interestingly, to match the observed CO(3-2) and CO(1-0) line ratio (**Figure 2**) we need gas whose temperature ($T_{gas}=27\pm^{11}_{4}$ K) is lower than that of cospatial optically thin blackbody dust grains (51 K). Kóspál et al. 2013 also find that in HD 21997 the gas excitation temperature implied by the CO lines is lower than the expected dust temperature. While models of gas in debris disks predict gas temperatures higher than the dust temperature (Kamp & van Zadelhoff 2001), the high mass of the HD 141569 disk may mean it is in a regime where CO is the main coolant, rather than [OI] and [CII]. In this regime, the gas temperature can drop below that of the dust. NLTE effects may also apply, causing the excitation temperature to diverge from the gas kinetic temperature. Under the assumption of $CO/H_2=10^{-4}$, as expected for gas leftover from the protoplanetary disk, this system is in LTE. A diminished H_2 abundance, as expected if the gas is released by collisions of gas-rich comets, could lead to significant NLTE effects. Further work is needed to explore fully the possibility of a low-density NLTE dominated disk as a fit to the observed CO emission.

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TWO SWARM QUADRANTS DEPLOYED: TRIPLING SMA BANDWIDTH AND ENABLING 32 GBPS PHASED ARRAY VLBI

SWARM Development Team

Two quadrants of the new SWARM[1] correlator have been available for SMA science since March 2016. Together with the SMA's traditional ASIC correlator, SWARM now triples the SMA's instantaneous bandwidth. We are presently purchasing additional ROACH2[2] assemblies, network switches, and other equipment to build the third and fourth quadrants of SWARM. By the end of 2016 we expect to have four SWARM quadrants in operation, quadrupling the SMA's bandwidth to 32 GHz for both sidebands in dual-receiver mode. The ASIC correlator will be retired during the quadrant 3 and 4 build out.

At full design speed, a quadrant of SWARM will process either 2 GHz of usable bandwidth per polarization in full Stokes polarization mode, or 4 GHz of bandwidth from a single receiver. The current iteration of the SWARM FPGA bit code runs at 10/11 of the design speed, meaning that we currently process 91% of the design bandwidth. We expect to achieve full speed operation ahead of the full four-quadrant buildout. Table 1 presents the design specifications and current performance of SWARM. Recent astronomical data acquired with SWARM are presented in **Fig. 1 – Fig. 3**.

The SWARM Phased ArrayFunction

SWARM features a built-in beamformer that enables the SMA to operate in a phased array mode. The beamformer is especially important for participation in VLBI observations, and combines all antennas to perform as the equivalent of a single station with a larger collecting area. Phasing the array requires tracking all sources of delay, including fluctuations in water vapor concentration in the atmosphere. The SWARM phasing system is equipped with a real-time phasing solver that continually updates the beamforming weights to compensate for these variable delays over the course of the observation. **Fig. 4** is a plot showing phasing efficiency over a typical night.

A detailed discussion of the SWARM phased array mode and its performance is given in SMA Memo 163.

APHIDS Data Processing of VLBI Data

The data produced by the SWARM phased array, which are sampled in the frequency domain, and at a rate which is a multiple of 416 Msps, cannot be correlated directly with data recorded at other EHT stations, which are sampled in the time domain at 4096 Msps. To reformat the SWARM data to be compatible

Feature	*Specification*	*10/11 mode*	*remarks*
Number of antennas	8	8	Each antenna has 2 receivers
Number of baselines	56	56	28 per receiver; 128 total in full Stokes mode including autocorrelations
Bandwidth per receiver	2 GHz	1.8 GHz	Usable bandwidth after excluding 15% guard band
Number of polarizations	2	2	DSB Rx, Walsh functions split SBs
Channel Bandwidth	140 kHz	129 kHz	2.3 or 2.1 GHz/16384 channels

Table 1: SWARM specifications showing those for the full design goal and the 10/11 mode

[1]SWARM: SMA Wideband Astronomical ROACH2 Machine
[2] ROACH2: Reconfigurable Open Architecture Computing Hardware version 2

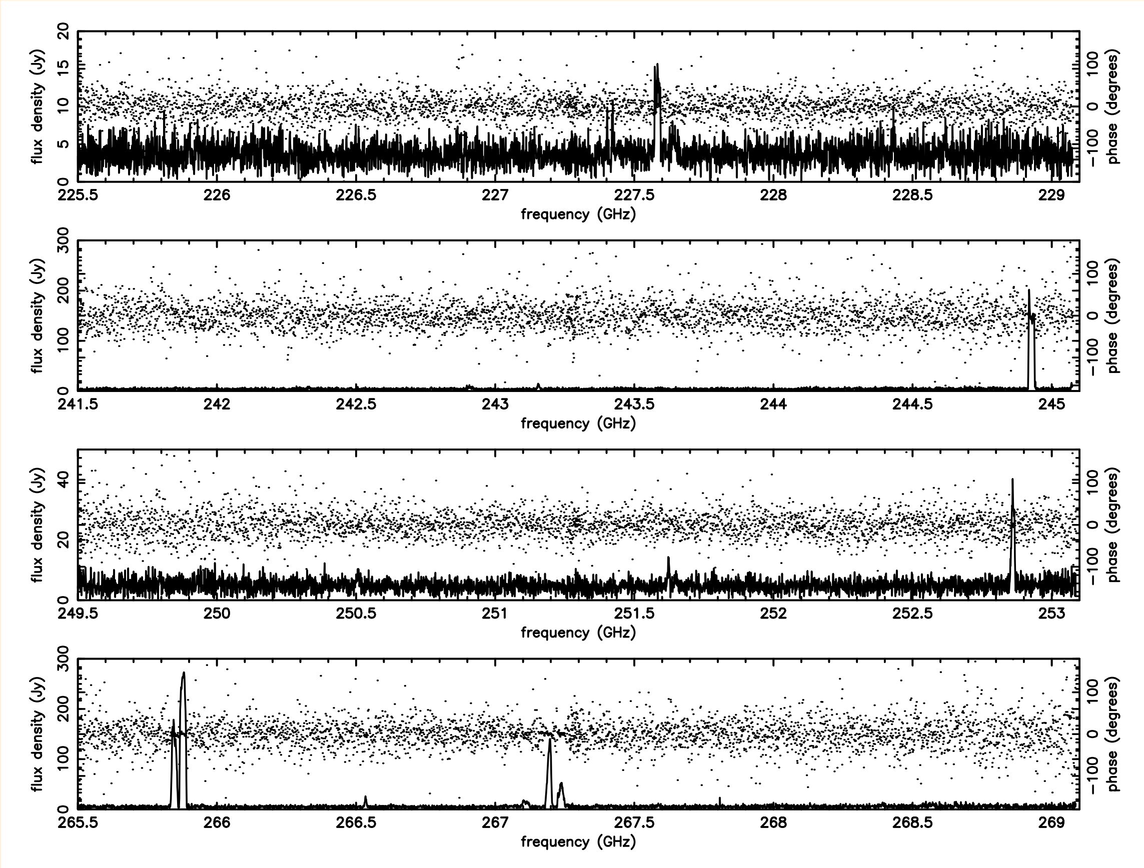


Figure 1: Spectra from SWARM running in dual quadrant dual receiver mode, with the 200 and 240 GHz receivers tuned to local oscillator frequencies of approximately 235.3 and 259.3 GHz respectively. The SMA was pointed towards IRC+10216 for about 5 minutes on 10 June 2016. From the top panel down spectra for of 200 GHz LSB, 200 GHz USB, 240 GHz LSB, and 240 GHz USB are shown. Each panel shows both the amplitude (lines) and the phase (points) against sky frequency. Each plotted point is an average of eight SWARM channels.

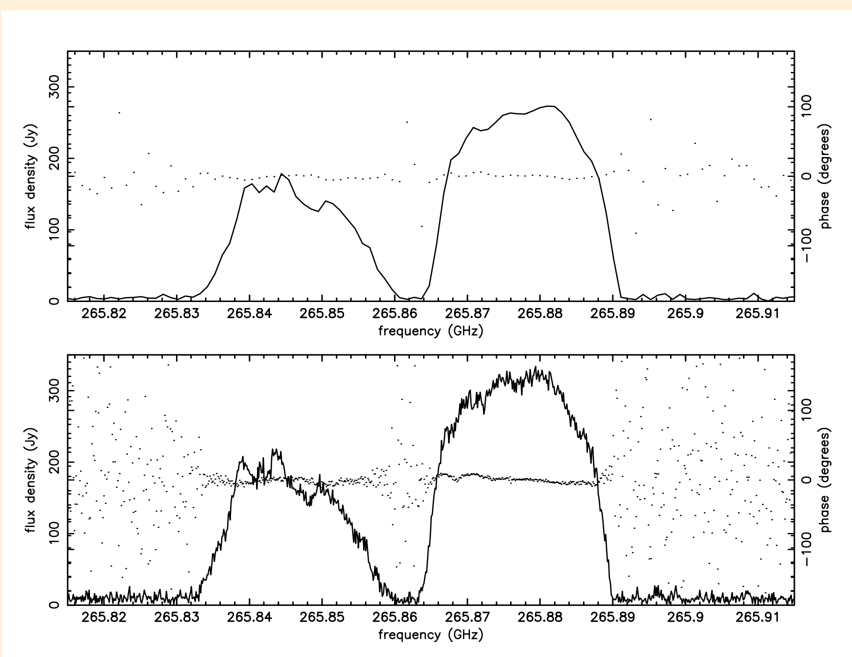


Figure 2: An expanded view of the HCN line pair towards the left of the bottom panel in Fig. 1. The line on the left is the HCN $\nu 2 = 1$, $J = 3 \mapsto 2$ vibrationally excited line at rest frequency 265.852 GHz, and the line at the right is the HCN $J = 3 \mapsto 2$ pure rotation line with rest frequency 265.885 GHz. In this figure, the top panel has had 8-channel smoothing applied as in **Fig. 1**, while the bottom panel shows SWARM data at its native spectral resolution of 128 kHz. Though some of the fine structure in the amplitude is noise, there is evidence of intrinsic structure discernable at the finer resolution, especially in the phase.

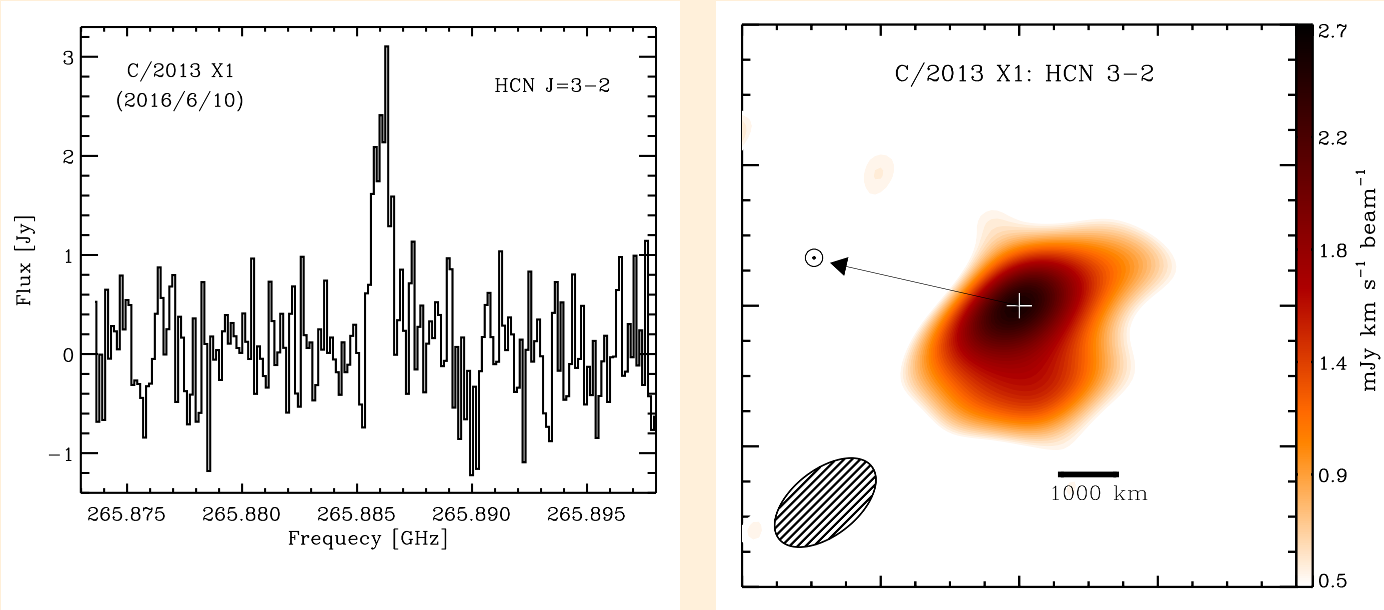


Figure 3: SMA HCN J=3→2 spectrum (left) and image (right) toward comet C/2013 X1 (PanSTARRS). The observations were taken on 10 June 2016 using the dual receiver SWARM mode with a spectral resolution of 127 kHz. This narrow line (left) is resolved with SWARM's high uniform spectral resolution. The integrated intensity image (right) shows the HCN emission peaked around the nucleus position but with clear extension toward the anti-solar direction. The cross marks the position of the comet's nucleus and the arrow shows the direction of the Sun. North is the positive Y-axis and East is the positive X axis. This data and description was reduced and kindly provided for this newsletter by Chunhua Qi.

with data from other EHT sites, a reprocessing system, called APHIDS (Adaptive Phased-array Heterogeneous Interpolator and Downsampler for SWARM) was developed. This system ingests raw SWARM data from a Mark6 VLBI recorder, does the required reformatting and resampling on multiple general purpose GPUs, and then records the produced data on a separate Mark6 VLBI recorder, as illustrated in **Figure 5**. The system has been used successfully to correlate SWARM data with data from other EHT sites since the 2015 EHT campaign.

April 2016 EHT Campaign: 32Gbps SWARM

The fourth night of the April EHT run included a four-hour engineering test with phased ALMA recording 37 dual polarization antennas. In addition to ALMA, SMA partnered with LMT (Mexico) and SMT (Arizona). Four earlier EHT tracks had been science tracks excluding ALMA but including LMT, SMT and JCMT (select track). EHT was not allocated time to run EHT science with phased ALMA—this test is an engineering verification step necessary (but not sufficient) to qualify the EHT and the APP (ALMA Phasing Project) to be allocated ALMA time for science.

On Maunakea things ran extremely smoothly since the first science track, with SWARM really hitting stride and running reliably in dual quadrant, dual receiver 10/11 phased array VLBI recording mode. SWARM simultaneously phased both the 230 GHz and 240 GHz receivers in opposite polarizations on the six SMA antennas so equipped. A seventh SMA antenna, or the JCMT when available, was configured as a comparison station, i.e. as a single dish VLBI station very useful for calibration. We also recorded separately the phased array reference antenna.

With dual quadrant dual receiver SWARM phasing and recording 8 GHz of IF, and single polarization 4 GHz recording of two single

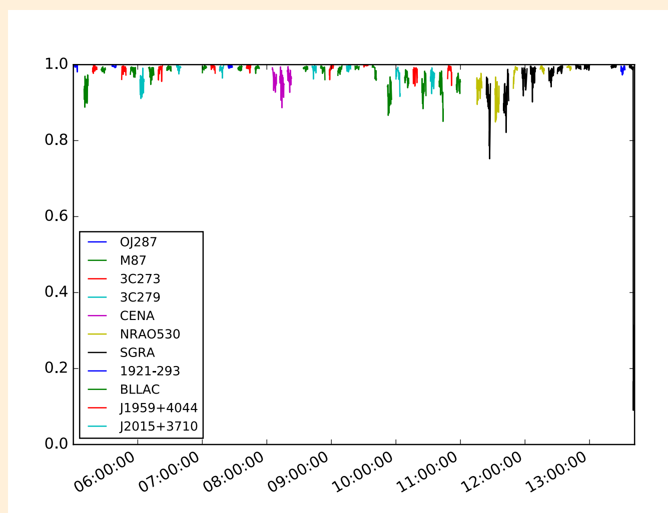


Figure 4: During EHT VLBI on April 4, 2016, phasing efficiency was measured on various sources. The horizontal axis shows time in UT and the vertical axis shows phasing efficiency.

dishes, an impressive aggregate VLBI recording rate of 64 Gbps using four Mark6 recorders was achieved—a record for a single VLBI site, and 4x the bandwidth of 2015. The excellent weather led to outstanding phasing efficiency. Fringes were obtained with the JCMT using their new receiver. When SMA ran without JCMT an SMA antenna was substituted for JCMT to maintain the Maunakea station's overall characteristics (bandwidth, polarizations & number of comparison antennas). SWARM proved to be reliable in VLBI mode, with operation virtually hands off all night.

The latest news is that SMA- SWARM is part of a closure phase triangle with LMT and ALMA, with detections on all three baselines spanning all four hours of the ALMA test window!

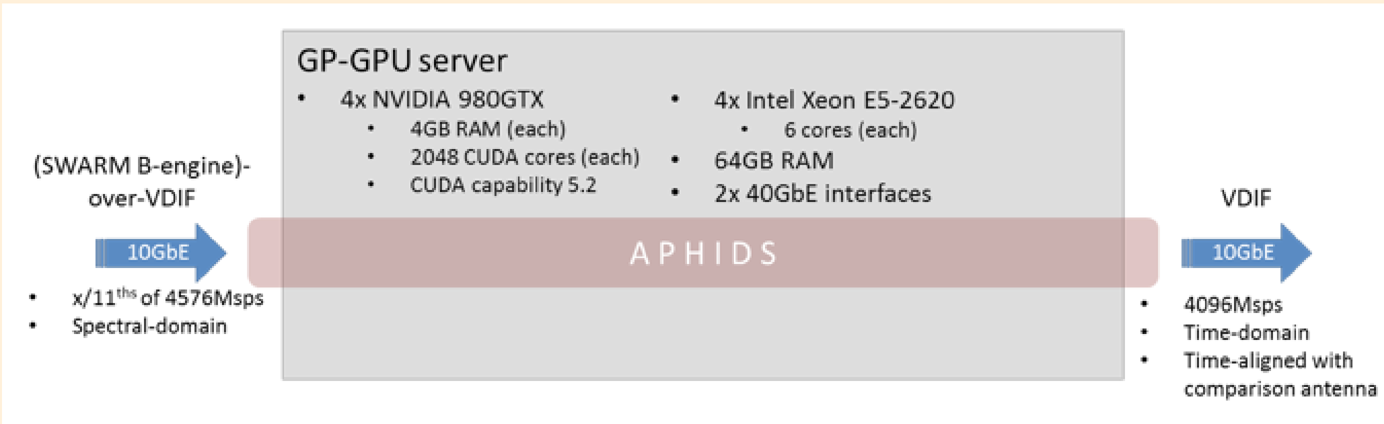


Figure 5: Showing the data flow in the APHIDS preprocessing system.

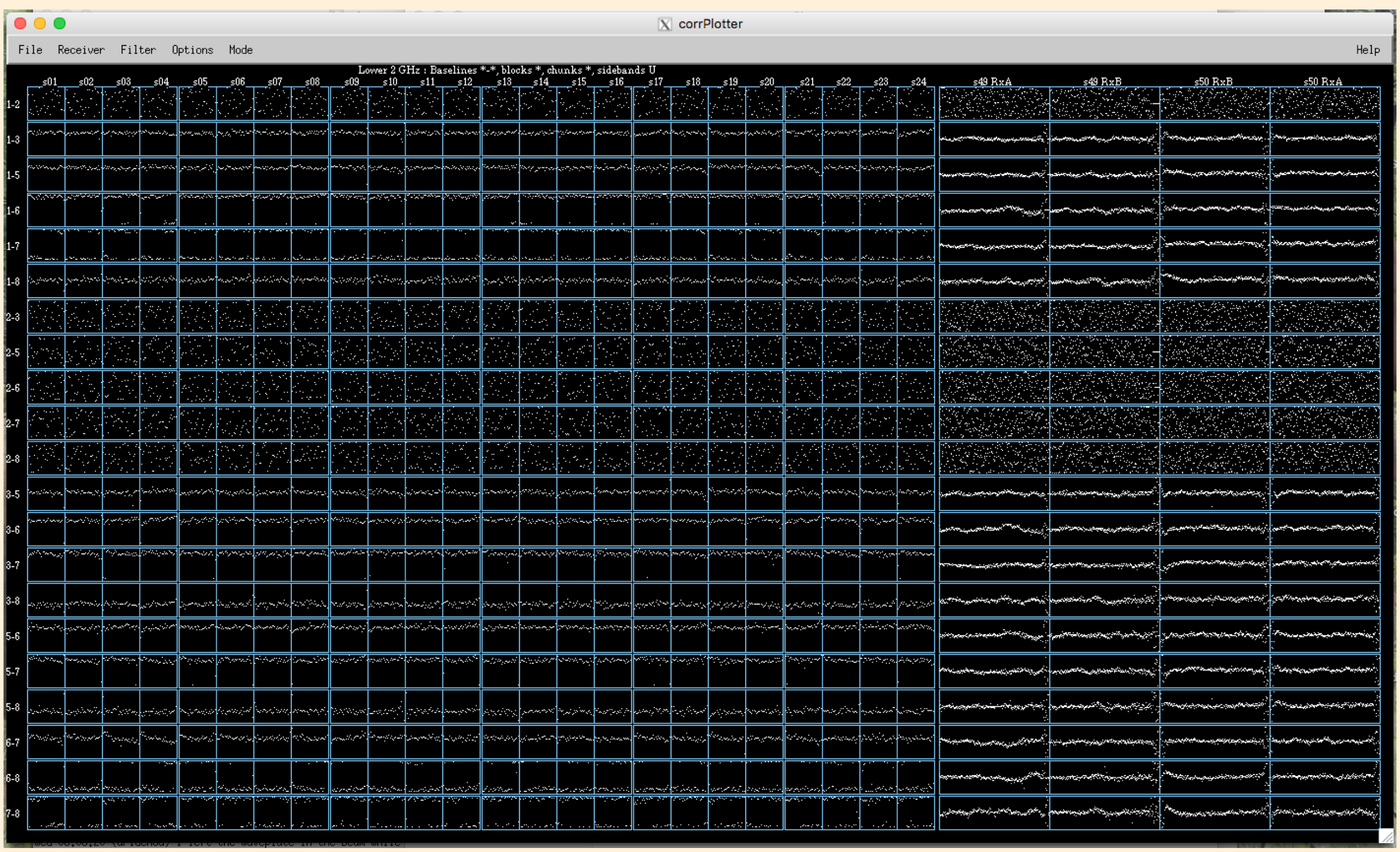


Figure 6: A typical corrPlotter screen shot showing two receivers over six antennas phased up (the lack of fringes on antenna 2 is expected since Walshing and lobe rotation are suppressed).

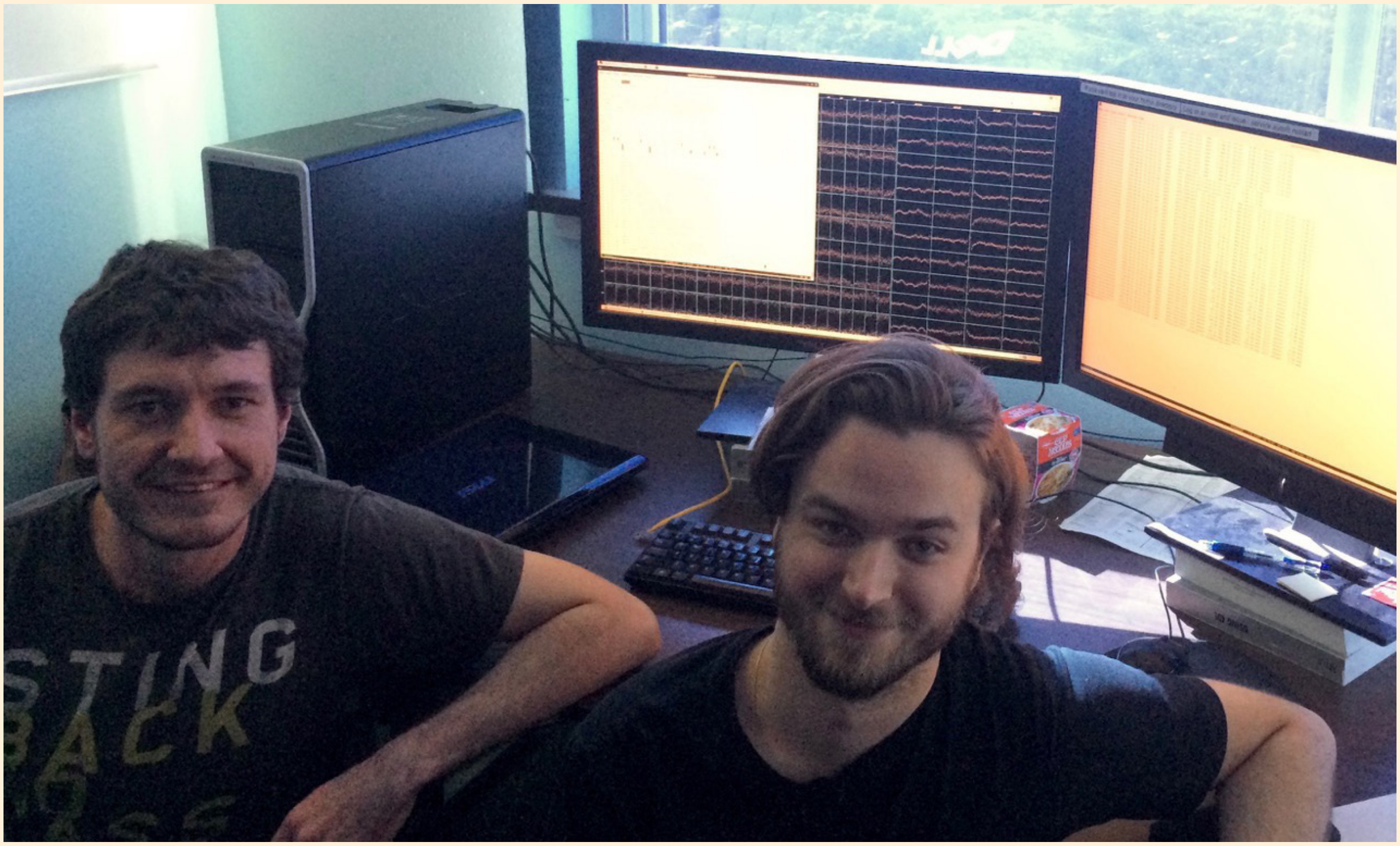


Figure 7: Happy faces (of André Young and Rurik Primiani) after the first dual pol, dual receiver, 10/11 SWARM phase-up.

IN REMEMBRANCE: ALICE ARGON

It is with great sadness that we report the passing of our long-time colleague Dr. Alice Argon. During her nearly 30 years at the Center for Astrophysics, she was widely respected for her experience and skill reducing and analyzing data from the VLA, VLBA, SMA, and ALMA. She played a key role in the landmark study of megamasers orbiting the supermassive black hole at the center of NGC 4258, taking the lead on a paper that reported a decade of VLBI observations.

Alice was a key member of the Radio Telescope Data Center, which provides access to data from the SMA, among other functions. Alice worked closely with the SMA staff since its commissioning in 2002, designing and coordinating web access to the SMA archive. She was responsible for the archiving, indexing, and distribution of SMA data through the web, and was the go-to person for problems concerning data access and data reduction with AIPS, MIR, Miriad, and CASA. Alice was most recently pioneering the use of CASA in parallel computing architectures, working closely with the SAO High-Performance Computing group. Alice will be fondly remembered as a meticulous and conscientious scientist who shared her skills daily with students, visitors, and colleagues.

Thomas Dame (Director, RTDC) with Mark Gurwell (SMA)

SMA SCIENCE IN THE NEXT DECADE

OCTOBER 27-28TH, 2016 TAIPEI, TAIWAN

http://events.asiaa.sinica.edu.tw/workshop/20161027/

Timeline:

- Registration deadline for the PRC Passport Holders: July 24, 2016
- Registration deadline: Aug. 31, 2016

Questions: sma2016@asiaa.sinica.edu.tw

Registration: https://events.asiaa.sinica.edu.tw/workshop/20161027/registration.php

The Submillimeter Array (SMA) has provided forefront capabilities for high spatial and spectral resolution observations at submillimeter wavelengths from its excellent site on Maunakea, Hawaii since 2004. SMA observations have resulted in new insights into a wide variety of astrophysical phenomena, from protoplanetary disks to high redshift galaxies. The much larger international Atacama Large Millimeter/submillimeter Array (ALMA) is now in routine operation at millimeter and submillimeter wavelengths. To maintain a leading role in the ALMA era, the SMA Project has embarked on an ambitious, staged, strategic upgrade to dramatically improve its sensitivity and observing speed. The new wideband SMA -- the wSMA — will be ideally suited to spectral line surveys and studies of submillimeter sources in the time domain, as well as a wealth of other applications. This workshop will provide a forum for astronomers from the SMA collaboration and user community to promote, discuss, and elaborate key science cases for wSMA observations in the next decade.

The workshop will also facilitate the forging of collaborations to help realize these new science opportunities.

The wSMA will impact a wide range of topics, including:

- High-Z Galaxies
- Nearby Galaxies
- Galactic Center
- Star Formation
- Circumstellar Disks
- Evolved Stars
- Solar System Objects
- Astrochemistry
- Time-Domain Astronomy
- EHT/VLBI
- Instrumentation

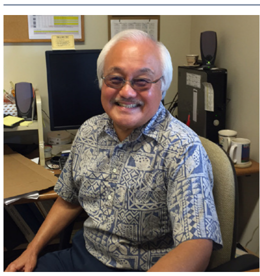
EDWARD TONG AWARDED SECRETARY'S RESEARCH PRIZE

Dr. Edward Tong is one of the recipients of the 2015 Secretary's Research Prizes which recognizes excellence in research conducted by employees of the Smithsonian Institution. The title of this research is: "A Microwave-operated Bolometric Detector for Terahertz Radiation", *IEEE Transactions on Applied Superconductivity*, Vol. 25, 2300604, June 2015.

PAUL YAMAGUCHI NAMED A 2016 UNSUNG HERO OF THE SMITHSONIAN

Paul is a Microwave Electronics Technician in Hilo. In addition to his primary task of installing and maintaining the fiber optics transmission and IF/LO systems on Maunakea, he makes important contributions to many other areas of telescope operation. We congratulate Paul on this award and thank him for his tireless efforts to make the SMA successful!

ALAN KUSUNOKI RETIRES AFTER 25 YEARS



Alan Kusunoki joined the SMA in September 1991 and retired at the end of April (24 years, 8 months). Alan led the development and construction of the SMA facilities, both on Maunakea and in Hilo. He was a major part of every milestone in project history. Jim Moran (former SMA Director) recalls his "first visit to the site on Maunakea in the early 1990s. Alan had just set up the one room office in the Federal building next to the Post Office in Hilo. The site was marked by just a stick in the ground. We have come a long way!"

Thank you, Alan, for your enduring contributions to the SMA over all these years. Happy Retirement!

STAFF CHANGES IN HILO

Sarah Stoebner, Observing Assistant, left in March to pursue new opportunities. Sarah's dedication to excellence was apparent to all her co-workers. We thank Sarah for spending three years with the SMA and wish her success!

Matthew Christisen, Electrical Technician, joined in May, reporting to John Maute. Matthew arrives from Waco, Texas, where he worked at a hydroelectric dam for the Army Corps of Engineers.

Miriam Fuchs, Observing Assistant, joined in April, reporting to Ryan Howie. A recent graduate of Haverford College, Miriam comes from Philadelphia, where she worked as an astronomy interpreter at the Franklin Institute.

Carolyn Ridderman, Administrative Staff Assistant, joined in March, reporting to Simon Radford. Before moving to Hilo, Carolyn worked in Honolulu for the Coast Guard and for NOAA.

Adam Weis, Observing Assistant, joined in June, reporting to Ryan Howie. Adam recently received his Master's degree in Astronomy from Columbia University.

SMA POSTDOCTORAL FELLOWS: COMINGS AND GOINGS

The Submillimeter Array Postdoctoral Fellowship program supports young scientists active in a variety of astronomical research fields involving submillimeter astronomy. The SMA Fellowship is competitive, and a number of our past Fellows have gone on to permanent faculty and research staff positions located around the world.

The SMA welcomes our newest Fellows:

Tomasz (Tomek) Kaminski comes to us from his current position as an ESO ALMA fellow stationed in Chile. He received his Ph.D. from the Nicolaus Copernicus Astronomical Center of the Polish Academy of Sciences (Warsaw) in 2010, advised by Romuald Tylenda with a thesis titled 'Observations of the light-echo material of V838 Monocerotis.' Dr. Kaminski has broad interests related to astrochemistry, stellar astrophysics, and transients, and has used the SMA in the past via a spectral-line survey to investigate the spatial distribution of many molecular species, including important dust-forming molecules, in the evolved massive star VY CMA.

Garrett (Karto) Keating received his Ph.D. from the University of California, Berkeley in May 2016, advised by Carl Heiles; his thesis title is 'The Undiscovered CO: Charting bulk molecular gas in the early Universe'. Dr. Keating's thesis work centered on researching the evolution of molecular gas in galaxies at z~3 using CO intensity mapping. He has extensive experience with the Hat Creek Radio Observatory and the CARMA observatory.

Dr. Kaminski and Dr. Keating will join continuing SMA Fellows Luca Ricci, Shaye Storm, and Junko Ueda in the fall.

As new Fellows arrive, we also take the time to thank those Fellows who are moving on to even bigger things:

- Lars Kristensen recently moved to Denmark, where is he is now Assistant Professor of Astronomy at the University of Copenhagen.
- Cara Battersby has accepted an NSF Astronomy and Astrophysics Fellowship, which she will occupy right here at the CfA. Cara will begin working as Assistant Professor of Astronomy at the University of Connecticut in fall 2017
- Michael Dunham will begin working as Assistant Professor of Physics at the State University of New York at Fredonia in August

A list of current and former SMA Fellows is provided at: https://www.cfa.harvard.edu/opportunities/fellowships/sma/smafellows.html

along with further information on the SMA Fellowship program. We anticipate the deadline for the 2017 SMA Fellowship opportunities will be in October 2016.

Mark A. Gurwell, Chair, SMA Fellowship Selection Committee

POSTDOCTORAL OPPORTUNITIES WITH THE SMA

The Submillimeter Array (SMA) is a pioneering radio interferometer designed for arc-second imaging in the submillimeter spectrum. SMA science spans an impressive array of fields, ranging from our solar system, through imaging of gas and dust and tracing magnetic fields in stellar nurseries and planet-forming disks, to exploration of nearby galaxies and imaging of dusty star-forming galaxies at high redshift. In addition to its outstanding record in astronomical research, the SMA is a world leader in the design of wide-bandwidth, high-frequency radio receivers for astronomy.

We anticipate offering one or more SMA Postdoctoral Fellowships starting Fall 2017. These positions are aimed chiefly at research in submillimeter astronomy, and successful candidates will participate in observations with the SMA, research in their interpretation, and/or instrument development. While the SMA fellowships are intended primarily for research associated with the SMA, our main offices at the Center for Astrophysics provide Fellows with unique opportunities to develop collaborations within the wider CfA community and enjoy extraordinary freedom in structuring their research activities. Applicants must have a recent Ph.D. in astronomy or a related field.

The SMA is a collaboration between the Smithsonian Astrophysical Observatory and the Academia Sinica Institute of Astronomy and Astrophysics in Taipei, Taiwan. The Smithsonian Astrophysical Observatory is an Equal Opportunity/Affirmative Action Employer where all qualified applicants receive equal consideration without regard to race, color, creed, national origin or gender.

Application information and instructions can be found at http://www.cfa.harvard.edu/opportunities/fellowships/sma

The deadline for applications has not yet been determined but is expected to be in October 2016. Please check the above link for up to date information on the deadline and application procedure.

Questions: smapostdoc@cfa.harvard.edu

CALL FOR SMA SCIENCE OBSERVING PROPOSALS

The joint CfA-ASIAA SMA Time Allocation Committee (TAC) solicits proposals for observations for the period Nov 16, 2016 – May 15, 2017 (2016B semester). The deadline for submitting proposals is August 11, 2016

The SMA Observer Center website: http://sma1.sma.hawaii.edu is expected to open for proposal submission on July 20, 2016.

PROPOSAL STATISTICS 2016A (16 MAY 2016 - 16 NOV 2016)

The SMA received a total of 79 proposals (SAO 57) requesting observing time in the 2016A semester. The proposals received by the joint SAO and ASIAA Time Allocation Committee are divided among science categories as follows:

Category	Proposals
high mass (OB) star formation, cores	20
low/intermediate mass star formation, cores	15
evolved stars, AGB, PPN	9
local galaxies, starbursts, AGN	8
submm/hi-z galaxies	8
protoplanetary, transition, debris disks	5
UH	4
GRB, SN, high energy	3
solar system	3
galactic center	2
other	2

TRACK ALLOCATIONS BY WEATHER REQUIREMENT (ALL PARTNERS):

PWV[1]	SAO	ASIAA	UH[2]
< 4.0mm	6A + 16B	5A + 5B	6
< 2.5mm	22A + 31B	5A + 5B	11
< 1.0mm	2A + 1B	0A + 0B	0
Total	**30A + 48B**	**10A + 10B**	**17**

(1) Precipitable water vapor required for the observations.
(2) UH does not list As and Bs

TOP-RANKED SAO AND ASIAA PROPOSALS – 2016A SEMESTER

The following is the listing of all SAO and ASIAA proposals with at least a partial A ranking with the names and affiliations of the principal investigators.

EVOLVED STARS, AGB, PPN

Nimesh Patel, CfA, SMA
Chemical Evolution from AGB to PN: A Spectral-line Survey of CRL 2688 and NGC 7027

GALACTIC CENTER

Hau-Yu Baobab Liu, ESO-Garching
First Submillimeter Interferometric Polarimetry of the Galactic Circumnuclear Ring

Howard Smith, CfA
Understanding How a Black Hole Feeds: SMA Observations of SgrA Simultaneous with Spitzer and Chandra*

GRB, SN, HIGH ENERGY

Alexandra Tetarenko, University of Alberta
Characterizing Rapid Millimeter Frequency Variability in Black Hole X-ray Binaries

HIGH MASS (OB) STAR FORMATION, CORES

Carmen Juarez, Institut de Ciències de l'Espai CSIC-IEEC
Assessing the role of magnetic fields in a filament with super-Jeans fragmentation

Keping Qiu, School of Astronomy and Space Science, Nanjing University
Completing the SMA survey of massive cores in Cygnus X

Qizhou Zhang, CfA
Constraining angular momenta in the disk wind using recombination masers in MWC349A

Sheng-Yuan Liu, ASIAA
Exploring the Molecular Content of the Infrared Jet-Outflow System in the Rare O-Type Protostar W42-MME

Tao-Chung Ching, National Tsing Hua University, Taiwan
Pilot mosaic polarization observations in Orion BN/KL and W51

Taylor Hogge, Boston University
Mapping Outflows in the Extreme High-mass Star-forming Region G23.33-0.30

LOCAL GALAXIES, STARBURSTS, AGN

Geoffrey Bower, ASIAA
Variability Timescale of Low Luminosity AGN (copied from 2015B-A003)

Wen-Ping Lo, ASIAA
Verify the black hole magnetosphere model for origin of very-high-energy gamma-ray emission in IC 310 with SMA polarimetry

LOW/INTERMEDIATE MASS STAR FORMATION, CORES

Chat Hull, Harvard-Smithsonian Center for Astrophysics (and NRAO)
Cepheus Polarization Survey: a Pilot Study

Naomi Hirano, ASIAA
Is the L1448C(N) protostellar jet "extremely active"? -- three dimensional kinematic structure probed by proper motions

PROTOPLANETARY, TRANSITION, DEBRIS DISKS

David Wilner, CfA
The HR 8799 Planetary System Debris DIsk

SOLAR SYSTEM

Charlie Qi, CfA
The Primary Volatile Composition of a Dynamically New Comet - C/2013 X1 (PanSTARRS)

Mark Gurwell, Harvard-Smithsonian Center for Astrophysics
The Surface and Atmosphere of Triton

SUBMM/HI-Z GALAXIES

Asantha Cooray, University of California, Irvine
High Resolution Imaging of Rarest and Brightest Herschel-selected sub-millimeter Galaxies

ALL SAO PROPOSALS - 2015B SEMESTER

The following is the listing of all SAO proposals observed in the 2015B semester (16 Nov 2015 - 15 May 2016)

Andrew Baker, Rutgers University
SMA mapping of ACT dusty star-forming galaxies

Geoffrey Bower, ASIAA
Variability Timescale of Low Luminosity AGN

Geoffrey Bower, ASIAA
Do the Accretion Environments of LLAGN Resemble that of Sgr A?*

Scott Chapman, Dalhousie University
Locating the bright submillimeter galaxy population with SMA in SCUBA-2 CLS fields

Yu-Ching Chen, ASIAA
Probing the protostar candidate in rho oph A region with H2COand CH3OH

Samantha Chen, National Tsing Hua University
Searching for the Compact High Velocity Components in the NGC 2264G Bipolar Outflow

L. Ilsedore Cleeves, SAO
Confirming Structure in the TW Hya Protoplanetary Disk

S. Michelle Consiglio, UCLA
Imaging Star Forming Clouds in CO(2-1) in NGC 2403

Lennox Cowie, University of Hawaii
A submillimeter survey of the GOODS/CANDELS/Chandra deep fields

Timea Csengeri, MPIfR
Peering into the dark: revealing the youngest massive protostars and their mass assembly process (copied from 2015A-S032)

Sheperd Doeleman, SAO
Polarimetric VLBI with the Event Horizon Telescope

Niklas Falstad, Chalmers University of Technology
Zw 049.057 - a greenhouse IR galaxy?

Giovanni G. Fazio, CfA
A Search for [OIII] and Continuum Emission in a Remarkably Luminous Galaxy at z = 11.09

Andrea Giannetti, Max Planck Institute for Radioastronomy
Molecular clouds and star formation at low-metallicity: the Far-Outer Galaxy

Josep Miquel Girart, CfA and Institut de Ciències de L'espai
Connecting magnetic fields from cores to disks

Mark Gurwell, CfA
Mapping the D/H Ratio in Martian Water Vapor

Viviana Guzman Veloso, CfA
Deuterium fractionation in low-mass prestellar and protostellar cores: N2D+/N2H+ and DCO+/HCO+

Nanase Harada, ASIAA
Predicting Quenching of Starburst with Molecules

J Hatchell, School of Physics, University of Exeter
FHSC candidates in Serpens South (copied from 2014B-S024)

Naomi Hirano, ASIAA
Probing the dense gas distribution in the B1 main core from 10,000 AU to 500 AU scale

Li-Yen Hsu, University of Hawaii
Characterizing Faint Submillimeter Galaxies with Cluster Lensing

Atish Kamble, CfA
The Unprecedented Metamorphosis of Supernova 2014C: from a Hydrogen-stripped to a Strongly Interacting Supernova

Sabine Koenig, IRAM France
Disentangling the dense gas in the Medusa merger

Marina Kounkel, University of Michigan
Search for thermal component of non-thermally radio emitting disk

Lars Kristensen, CfA
Methanol as a tracer of the embedded low-mass population in high-mass clusters

Wen-Ping Lo, ASIAA
Flux Survey of Low-Luminosity AGNs at 230 GHz

Xing Lu, CfA
High-mass Star Formation in Dense Cores Embedded in Filaments

Meredith MacGregor, Harvard University
Debris Disks Around Nearby Sun-like Stars: Structure of the 56 Aur Debris Disk

Dan Marrone, University of Arizona
Tracking Accretion onto Sagittarius A with SMA Polarimetry*

Luca Matrà, University of Cambridge
Probing the exocometary HCN/CO ice composition around beta Pictoris

Satoki Matsushita, ASIAA
Search for IR-Pumped HCN Masers toward the Seyfert 2 Nucleus of M51

Nimesh Patel, CfA
Chemical Evolution from AGB to PPN: A Spectral-line Survey of CRL 618 (copied from 2013B-S010)

Glen Petitpas, CfA
Warm gas in the disk of NGC2903

Basmah Riaz, MPE
Molecular outflow activity in proto-brown dwarfs

Luca Ricci, CfA
An SMA survey of protoplanetary disks in Serpens

Luca Ricci, CfA
AY191: Observations of GM Aurigae

Luca Ricci, CfA
AY191: Probing the morphology and kinematics of NGC3627

Victor M. Rivilla, Osservatorio Astrofisico di Arcetri

HCO as a precursor of astrobiological molecules

Laurence Sabin, National Autonomous University of Mexico (UNAM)
Probing magnetically collimated jets and outflows in evolved intermediate mass stars

Shaye Storm, CfA
A Tale of Two Cores: Stellar Birth in the Young L1451 Region

Ai-Lei Sun, Princeton University
Molecular Outflows in AGN Superbubbles

Shigehisa Takakuwa, ASIAA
SMA Study of the Envelope Gas Motions surrounding the Planet-Forming Disk in HL Tau

John Tobin, Leiden Observatory
Confirming a Rotationally-Supported Disk Around the Class 0 protostar BHR7

Junko Ueda, SAO
Investigating the physical properties of molecular gas in the eastern dust lanes of the Medusa merger

Yuji Urata, ASIAA
Search for Bright submm afterglows Associated with Gamma-Ray Bursts

Jonathan Williams, University of Hawaii
Large Gas-to-Dust Variations in the Binary Protoplanetary System SR24

Jonathan Williams, University of Hawaii
Follow-up of K2 "dipper" stars

Hsi-Wei Yen, ASIAA
Probing Drift Velocity: An Assessment of Magnetic Field Importance

Nannan Yue, National Astronomical Observatories, Chinese Academy of Sciences
Gas Motion in a Filamentary Core Transitioning from the Prestellar to Class-0 Stage

Title: Far Infrared Variability of Sagittarius A*: 25.5 hr of Monitoring with Herschel
Authors: Moraghan, Anthony; Lee, Chin-Fei; Huang, Po-Sheng; Vaidya, Bhargav
Publication: *Monthly Notices of the Royal Astronomical Society, Volume 460, Issue 2, p.1829-1838 (MNRAS Homepage)*
Publication Date: 08/2016
Abstract: http://adsabs.harvard.edu/abs/2016MNRAS.460.1829M

Title: H-ATLAS: A Candidate High Redshift Cluster/Protocluster of Star-Forming Galaxies
Authors: Clements, D. L.; Braglia, F.; Petitpas, G.; Greenslade, J.; Cooray, A.; Valiante, E.; De Zotti, G.; O'Halloran, B.; Holdship, J.; Morris, B.; Pérez-Fournon, I.; Herranz, D.; Riechers, D.; Baes, M.; Bremer, M.; Bourne, N.; Dannerbauer, H.; Dariush, A.; Dunne, L.; Eales, S.; Fritz, J.; Gonzalez-Nuevo, J.; Hopwood, R.; Ibar, E.; Ivison, R. J.; Leeuw, L. L.; Maddox, S.; Michałowski, M. J.; Negrello, M.; Omont, A.; Oteo, I.; Serjeant, S.; Valtchanov, I.; Vieira, J. D.; Wardlow, J.; van der Werf, P.
Publication: *Monthly Notices of the Royal Astronomical Society, Advance Access (MNRAS Homepage)*
Publication Date: 06/2016
Abstract: http://adsabs.harvard.edu/doi/10.1093/mnras/stw1224

Title: Rotating Bullets from A Variable Protostar
Authors: Chen, Xuepeng; Arce, Héctor G.; Zhang, Qizhou; Launhardt, Ralf; Henning, Thomas
Publication: *The Astrophysical Journal, Volume 824, Issue 2, article id. 72, pp. (2016). (ApJ Homepage)*
Publication Date: 06/2016
Abstract: http://adsabs.harvard.edu/abs/2016arXiv160206350C

Title: Discovery of an Extremely Wide-angle Bipolar Outflow in AFGL 5142
Authors: Liu, Tie; Zhang, Qizhou; Kim, Kee-Tae; Wu, Yuefang; Lee, Chang-Won; Goldsmith, Paul F.; Li, Di; Liu, Sheng-Yuan; Chen, Huei-Ru; Tatematsu, Ken'ichi; Wang, Ke; Lee, Jeong-Eun; Qin, Sheng-Li; Mardones, Diego; Cho, Se-Hyung
Publication: *The Astrophysical Journal, Volume 824, Issue 1, article id. 31, pp. (2016). (ApJ Homepage)*
Publication Date: 06/2016
Abstract: http://adsabs.harvard.edu/abs/2016arXiv160403548L

Title: A Hot and Massive Accretion Disk around the High-mass Protostar IRAS 20126+4104
Authors: Chen, Huei-Ru Vivien; Keto, Eric; Zhang, Qizhou; Sridharan, T. K.; Liu, Sheng-Yuan; Su, Yu-Nung
Publication: *The Astrophysical Journal, Volume 823, Issue 2, article id. 125, pp. (2016). (ApJ Homepage)*
Publication Date: 06/2016
Abstract: http://adsabs.harvard.edu/abs/2016arXiv160400523C

Title: Protostar L1455 IRS1: A Rotating Disk Connecting to a Filamentary Network
Authors: Chou, Hsuan-Gu; Yen, Hsi-Wei; Koch, Patrick M.; Guilloteau, Stéphane
Publication: *The Astrophysical Journal, Volume 823, Issue 2, article id. 151, pp. (2016). (ApJ Homepage)*
Publication Date: 06/2016
Abstract: http://adsabs.harvard.edu/abs/2016ApJ...823..151C

Title: Understanding discs in binary YSOs - detailed modelling of VV CrA
Authors: Scicluna, P.; Wolf, S.; Ratzka, T.; Costigan, G.; Launhardt, R.; Leinert, C.; Ober, F.; Manara, C. F.; Testi, L.
Publication: *Monthly Notices of the Royal Astronomical Society, Volume 458, Issue 3, p.2476-2491 (MNRAS Homepage)*
Publication Date: 05/2016
Abstract: http://adsabs.harvard.edu/abs/2016MNRAS.458.2476S

Title: Constraints on the circumstellar dust around KIC 8462852
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