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FROM THE DIRECTOR

Dear SMA Newsletter readers,

I am pleased to congratulate Thomas Kaminski (ESO Chile and MPI Bonn), Hua-Bai Li (The Chinese University of Hong Kong), Jean Turner (UCLA) and their colleagues for their recent publications in Nature, summarized in this Newsletter. Collectively these publications highlight the relative ease and utility of the SMA to observe bright, chemically rich, galactic sources, and nearby galaxies; and further demonstrate the SMA's relatively unique polarization capability.

I would also like to thank members of the SMA correlator group for their continued efforts to provide additional wideband signal-processing capacity. We now regularly observe with the first tranche of SWARM, albeit at 3/4 speed, in parallel with the aging ASIC correlator, in service since 2002. While not yet perfect, the additional 2x1.5 GHz bands, coupled with the original 2x2 GHz bands of the ASIC correlator and double sideband receiver operation result in an instantaneous bandwidth of 14 GHz. This provides additional flexibility during spectral line observations and improves the continuum sensitivity of the SMA by about 40%. The SMA call for proposals for semester 2015B (16th November 2015 to 15th May 2016) reflects this additional capacity, so please consider taking advantage of this during proposal preparation.

Ray Blundell

NUCLEAR ASHES AND OUTFLOW IN THE ERUPTIVE STAR NOVA VUL 1670

T. Kaminski[1,2], K. M. Menten[2], R. Tylenda[3], M. Hajduk[3], N. A. Patel[4], A. Kraus[2]

CK Vulpeculae was observed in outburst in 1670-1672 by Hevelius [1] but only in 1982, a bipolar nebula was revealed at its location [1-3]. No stellar source has been seen in CK Vul, but radio continuum emission was discovered at the expansion center of the outflow [3]. We observed CK Vul using the APEX telescope and found a surprisingly rich chemistry. Subsequent higher angular resolution observations with the SMA revealed a bipolar outflow of about 15" with lobes along north-south, and a mm wavelength continuum source coincident with the previously known cm radio continuum [4].

A spectral-line survey of CK Vul carried out with the APEX telescope, revealed a rich set of molecules in this source. Selected spectra are shown in **Figure 1**. The detected molecular species suggest that nitrogen abundance is highly enhanced in CK Vul, and that the circumstellar envelope is not dominated by oxygen, although some strong lines of oxygen bearing molecules are seen, e.g., CO, SiO, H_2CO and HCO^+. (These molecules are also typically seen in carbon-rich stellar envelopes). All the nitrogen-bearing molecules are also seen in the envelopes of the yellow supergiant IRC+10420 and the luminous blue variable eta Carinae; CK Vul is only the third known such object. To obtain higher angular resolution information on the spatial distribution of some of these molecules, we observed CK Vul with the SMA. We discovered a bipolar outflow in CO of about 15" in size, much smaller than the known ionized nebula which has a size of about 71" **(Figure 2)**. We modeled the CO outflow with two overlapping hourglass shells observed at very low inclination angles. Most of the molecular lines emission arises in a compact central source of about 2", only partially resolved in the SMA observations. The observed misalignment of the long axis of the molecular region with respect to the axis of the large-scale optical nebula might be

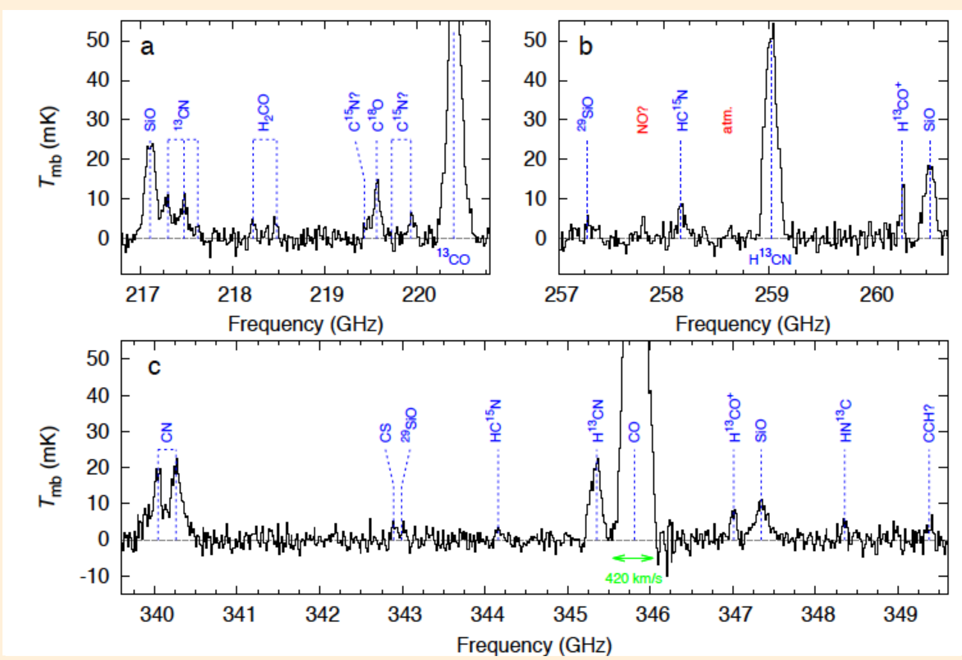

Figure 1: Sample spectra of CK Vul obtained with the APEX telescope showing the richness of molecular content. Lines of CO, CS, SiO, CN, HCN, HNC, HCO^+, N_2H^+ and H_2CO and their isotopologues were observed.

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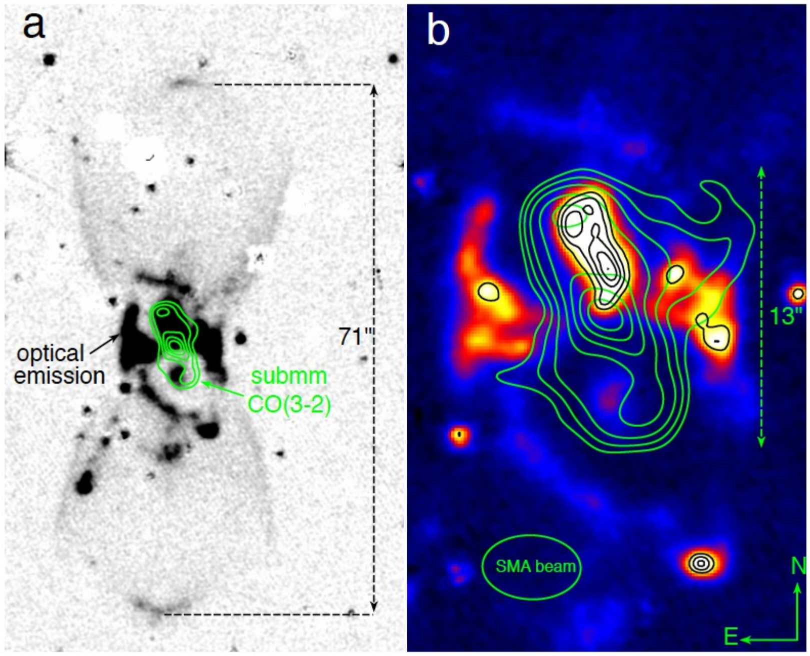

Figure 2: The ionized nebula and the newly discovered molecular emission in CK Vul. (a): The image shows the Hα+[NII]nebula created in the 17th century explosion. Bright stars were removed from this optical image. Green contours show the emission in the CO J=3-2 transition observed with the SMA (at 29, 43, 57, 72 and 86% of the peak). (b): Central part of the nebula is shown in color scale with yellow showing the brightest parts and blue the faint emission. The structure of the bright optical set is shown with black contours. Two extra contours are drawn for CO emission at 12 and 20% of the peak intensity.

caused by precession. SMA observations also revealed continuum emission, presumably due to thermal dust emission. The position of this continuum emission coincides with the previously observed cm wavelength radio continuum emission. The millimeter continuum emission indicates the presence of a flattened dusty envelope, and perhaps a torus and a pair of collimated jets. SED analysis of all available continuum measurements ranging from micrometer to cm wavelengths indicate that the emission is dominated by dust at a temperature of about 15 K with some dust at up to 50 K. The CO column density of 4x 10^{17} cm^{-2} implies a total mass of the gas to be about 1 solar mass. Although uncertain (due to assumed CO to hydrogen abundance), this mass is much higher than what classical-nova explosions can accumulate during their life-time [5].

The presence of strong submillimeter wavelength molecular emission itself makes CK Vul an extraordinary eruptive variable since classical novae do not show such emission. We confirmed this by observing 17 Galactic novae with the APEX telescope. None of these sources showed any submm emission lines. The central object of CK Vul may in fact be hostile to molecules due to extremely high UV radiation field. The presence of ionic species such as HCO^+ and N_2H^+ suggests a high abundance of H_3^+ which is required for their formation. H_3^+ can be formed from H_2 exposed to UV or shocks, the latter is more favorable due to the presence of jets, and high outflow velocity of 210 km/s observed in CK Vul.

The presence of molecules and a bipolar outflow makes CK Vul similar to a proto-planetary nebula, a short lived evolutionary object transitioning from low to intermediate mass AGB stars towards becoming a planetary nebula, e.g., OH 231.8+4.2 or CRL 618. But the SED of CK Vul implies a luminosity of about 1 $L_\odot$, while PPNe reach luminosities of about 10^4 $L_\odot$. The chemical composition in CK Vul is also unusual for a PPN, with very high nitrogen enhancement, and the presence of lithium in the outflow [6].

The strongest argument for CK Vul being indeed a truly unique transient comes from our analysis of its isotopic abundances. **Table 1** shows the column density ratios of various isotopologues, compared to the corresponding solar values. The isotopic ratios are extremely anomalous, suggesting nuclear processing of the circumstellar gas. This pattern of isotopic ratios cannot be pro-

Table 1: Isotopic ratios of the molecular gas of CK Vul

Isotopologue	Column-density ratio	Solar value
$^{12}C^{16}O/^{13}C^{16}O$	6 ± 2	$^{12}C/^{13}C=89$
$^{12}C^{16}O/^{12}C^{18}O$	23 ± 15	$^{16}O/^{18}O=499$
$^{12}C^{16}O/^{12}C^{17}O$	$\gg225$	$^{16}O/^{17}O=2682$
$H^{12}C^{14}N/H^{13}C^{14}N$	3 ± 1	
$H^{12}C^{14}N/H^{13}C^{15}N$	26 ± 9	$^{14}N/^{15}N=272$
$^{12}C^{14}N/^{13}C^{14}N$	~2	
$^{12}C^{14}N/^{13}C^{15}N$	$\sim4^\dagger$	
$H^{12}CO^+/H^{13}CO^+$	2 ± 1	
$^{28}SiO/^{29}SiO$	4 ± 4	$^{28}Si/^{29}Si=20$

†based on uncertain identification

Table 1: Isotopic ratios of the molecular gas of CK Vul.

duced by an AGB or post-AGB/PPN object [7]. The observed isotopic ratios cannot be reconciled with our current understanding of thermonuclear runaway nucleosynthesis, because nova ashes have a much lower $^{16}O/^{17}O$ ratio [8].

CK Vul's 17th century explosion may be most likely due to a merger of stars, as suggested to be an explanation for red transients [9]. The explosion could have been violent enough to penetrate and eject inner parts of the merging stars, exposing material that was active in nuclear burning. Not all of the observed isotopic signatures fit the models of non-explosive hydrogen burning in the CNO cycles [10], since the $^{15}N/^{14}N$ and $^{16}O/^{18}O$ ratios are too high. However, a merger remnant could be a complex mixture of processed and unprocessed gas and no quantitative predictions exist yet for the chemical composition of such an exotic star and its circumstellar envelope.

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MAGNETIC FIELDS SHAPE MOLECULAR CLOUD STRUCTURES

A Summary of Li et al (2105), Nature 520:518, by T. K. Sridharan

The role of magnetic fields in determining the structure, stability and fragmentation of molecular clouds is a subject of continuing debate. Recent enhancements to our capabilities in measuring the polarization of thermal continuum emission from dust on multiple scales and multiple objects are beginning to critically inform this debate. There is long standing realization that molecular clouds are non-thermally supported against gravity - the star formation time scale is longer than cloud free-fall time scales, the masses and sizes of cloud structures exceed thermal Jean's mass and length scales. Supersonic line-widths of molecular spectral lines suggest turbulent motions as a source of support. The presence of magnetic fields in molecular clouds has also been known for a long time, but whether the role of the magnetic fields dominates that of turbulence has not been clear, primarily due to the difficulty in observing the magnetic fields. In other words, the question of whether turbulence is sub- or super-Alfvenic (the strong and weak field models, respectively) is only beginning to be observationally studied. These studies have primarily focused on measuring the orientation of the magnetic field on as many objects as possible on at least two spatial scales and comparing them (e-g. Li et al., 2009, Zhang et al., 2014). They find that there is significant correlation between the orientations on large and small scales, which would not be possible if dominant turbulent motions randomized the B-field orientations. The paper being summarized here focused on a single region for an in-depth study, characterizing the B-field morphology on multiple nested scales spanning ~3 orders of magnitude, for the first time. It finds the B-field orientation to be aligned on all the scales studied (except when strong local feedback effects from star-formation are present), thus supporting the case for sub-Alfvenic turbulence. It also finds B-field morphologies, fragmentation signatures and density dependence consistent with magnetically regulated processes. The Submillimeter Array (SMA) contributed the data on the smallest scales.

Molecular clouds contain spinning non-spherical dust grains with their short axes aligned parallel to the magnetic fields. Thus, thermal emission from such aligned grains is polarized perpendicular to the B-field while optical radiation from background stars shining through the clouds is polarized parallel to the B-field due to preferential extinction. The outer regions of molecular clouds can be probed using polarization of light from background stars and regions with higher extinctions can be probed by thermal emission in millimeter and submillimeter wavelengths. These are the techniques used in this study.

The target of the the study, NGC6334, is a massive star-forming region in Cygnus, at a distance of 1.7 kpc. The B-field on 100 pc scales was measured using archival optical polarimetry data on background stars. The polarized thermal submillimeter emission from dust was measured using multiple telescopes for different smaller spatial scales. The Submillimeter Polarimeter for Antarctic Remote Observing (SPARO), the Caltech Submillimeter Observatory (CSO)/Hertz and the Submillimeter Array (SMA), with progressively higher angular resolutions were used to map the polarized dust emission at 10, 1 and 0.1 pc scales respectively.

Figure 1 shows the results from this multi-wavelength, multi-scale observations. As can be seen, the orientation of the magnetic field is maintained across the spatial scales with deviations less than 30 degree. This suggests for the first time sub-Alfvenic turbulence over this large range of scales spanning a factor of 10^3. In addition, dust emission elongated perpendicular to the B-field, pinched morphology and fragments towards the rims near the points of pinching, seen on all scales, point to the importance of the B-field in the core and clump formation processes. Region IV has significant star-formation activity and does not follow this pattern with less severe discrepancy in region I. The deviations are ascribed to feedback from the young stars.

Using force equilibrium between gravitational, magnetic tension and magnetic pressure forces, the B-field strength is estimated to be 0.2, 1.2 and 12 mG respectively for the 10, 1 and 0.1 pc scales. The range of gas densities on the multiple scales allows a study of the density dependence of the strength of the B-field, which is found to be $B \sim n^{0.41 \pm 0.04}$. The expected exponents are 2/3 for isotropic collapse where magnetic field is unimportant and 0 (no dependence) when the B-field completely restricts the gas flow.

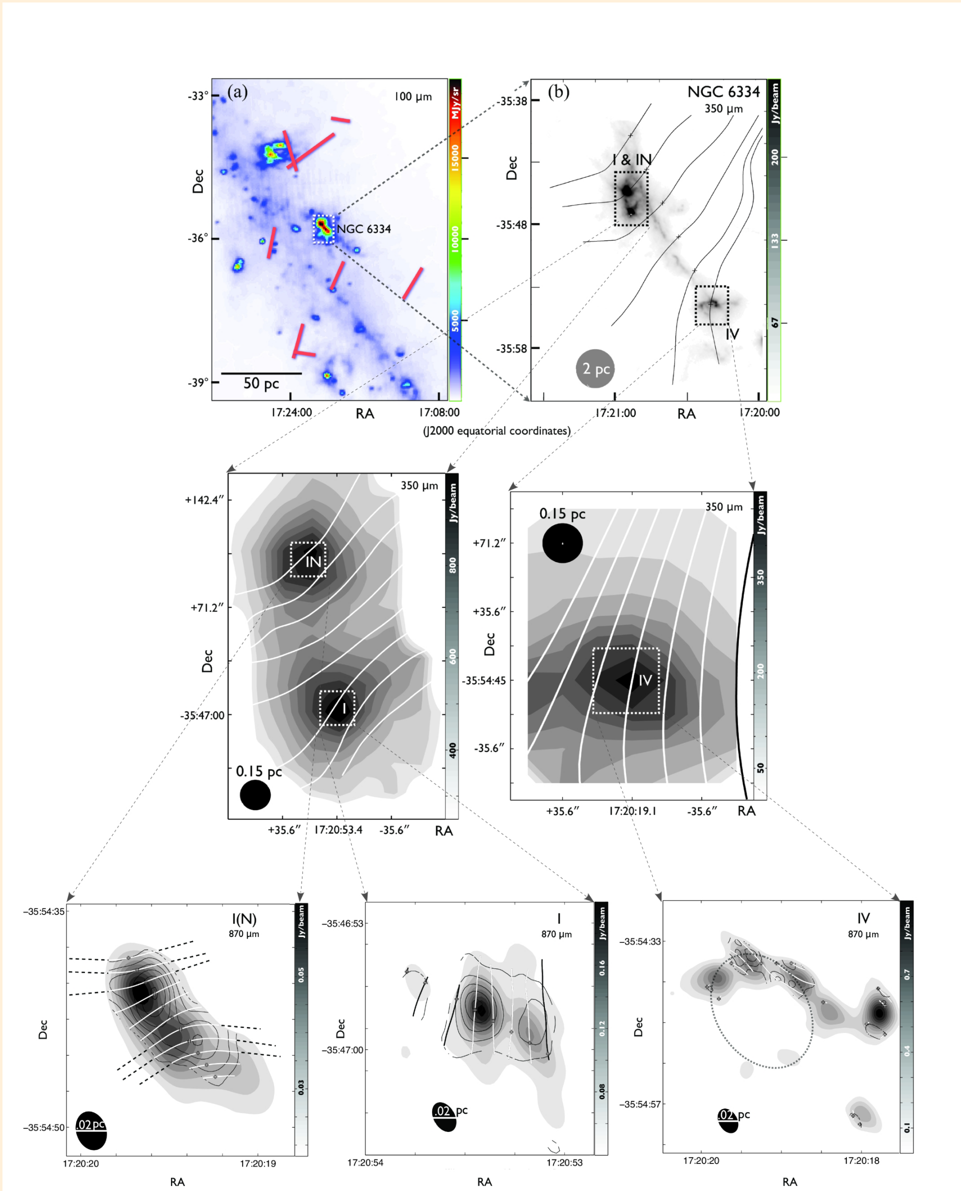

Figure 1: Top row: (a) B-field directions (red) inferred from optical polarimetry overlaid on IRAS 100-µm emission. (b) B-field lines inferred from SPARO 450-µm polarimetry overlaid on a 350-µm map. The filamentary cloud 'pinches' the field lines and the intensity peaks at the two ends of the filament (dashed rectangles). Middle row: Clumps observed by Hertz/Caltech Submillimeter Observatory (CSO). Bottom row: Cores observed by the SMA. Some field lines are extended (as dashed lines to help visualize the pinches). The oval indicates a shell H II region. The black contours show the relative intensity of the polarized flux, overlaid on the continuum emission in gray scale.

The lower exponent found is another indication that the B-field is strong enough to channel contraction.

In summary, the study presents multiple lines of evidence that point to the dominant role magnetic fields play in the cloud, clump, core and star-formation processes. In these observations, the SMA allowed access to the smallest spatial scales due to its high angular resolution polarimetric imaging capability, which is a unique strength of the instrument.

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A COSMIC FACTORY OF STARS AND SOOT – SMA REVEALS A SUPER STAR CLUSTER OF HIGHLY EFFICIENT STAR FORMATION IN NGC 5253

Turner, J. L. (UCLA), Beck, S. C. (University of Tel Aviv), Benford, D. J. (NASA), Consiglio, S. M. (UCLA), Ho, P. T. P. (ASIAA), Kovács, A.(Caltech), Meier, D. S. (NMIMT), Zhao, Jun-Hui (Harvard-Smithsonian CfA)

A group of astronomers lead by Professor Jean Turner from UCLA observed CO (3-2) towards the starburst region of NGC 5253 with the Submillimeter Array (SMA). A molecular streamer is revealed in CO, coinciding with the optical dust lane to the southeast of the massive star cluster located at the bright CO peak known as Cloud D [1]. The SMA observations provide significant evidence for the formation of the youngest known super star cluster with age of 3.5-4 Myr in this nearby dwarf galaxy. The high star formation efficiency in Cloud D appears to be extraordinary, at least tenfold higher as compared to that in Milky Way. Such a high efficiency is usually postulated for the massive globular clusters at the time when they formed ten billion years ago. The new finding with the SMA by Turner et al. has been published in the March 19, 2015 issue of Nature [2].

Located at a distance of 3.8 Mpc [3], NGC 5253 is one of the nearest blue compact dwarf (BCD) galaxies [4][5][6], a member of the Centaurus A / M 83 local group **(Figure 1)**. A violent star formation activity in forming the youngest known super star cluster (SSC) has been revealed in this nearby BCD [7][8]. Hundreds of SSCs with ages between 3.5 million to a billion years have formed in NGC 5253 [9][10][11][12]. With a poor metallicity and rich gas content, the BCD galaxies contain molecular clouds that are quite similar to the primeval clouds where formed the first generation stars in the early universe. The BCD galaxies appear to be an ideal test bed for better understanding the primordial star-forming process after the Big Bang. NGC 5253 contains a giant dust cloud, hiding clusters of more than one million stars, among them up to 7,000 stars equivalent to spectral type O7 [7][8]. NGC 5253 radiates a total luminosity of more than one billion solar luminosities in IR band.

The giant molecular cloud (GMC) called **Cloud D** was detected in CO (2-1) [1] with the Owens Valley Millimeter Array. Towards the central SSC, Cloud D, in NGC 5253, the activities in optical and near IR bands are heavily obscured with dust extinction measurements of $A_V \geq 16$ mag [2].

Recent SMA images of CO (3–2) *definitively* revealed the GMC associated with the super nebula, Cloud D, shown in **Figure 2** [2]. Cloud D is bright in CO (3–2) emission with an intensity ratio $I_{32}/I_{21} = 2.6 \pm 0.5$ as compared to the CO (2-1) emission, suggesting the molecule is highly excited with a temperature of at least 200K in the entire GMC. This is not surprising given the 7000 O7

Figure 1: Prominent members in the well-known Centaurus A / M 83 group – M 83, NGC 5253, NGC 4945 and Centaurus A or NGC 5128 (from left to right, not in same scale).

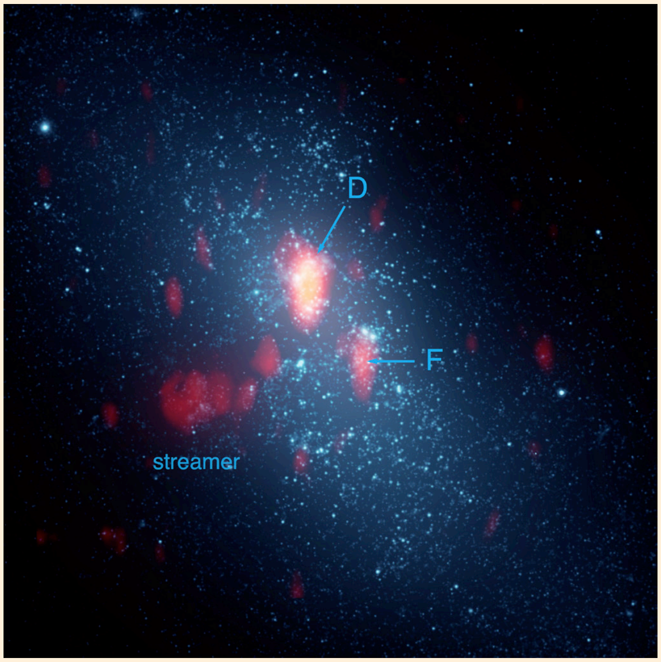

Figure 2: CO J=3-2 emission in NGC 5253. The SMA CO (3-2) integrated line intensity, in red, is shown atop a λ814nm Hubble Space Telescope image. The SMA beam is 4" x 2" (74 pc x 37 pc). The field covers 40" x 40" (740 pc x740 pc), north up, east left. Image registration is to < 1". The CO streamer coincides with the optical dust lane to the east. The super star cluster (SSC) is located at the bright CO peak, Cloud D; the SSC is embedded and not visible here. Cloud F is to the southwest of Cloud D.

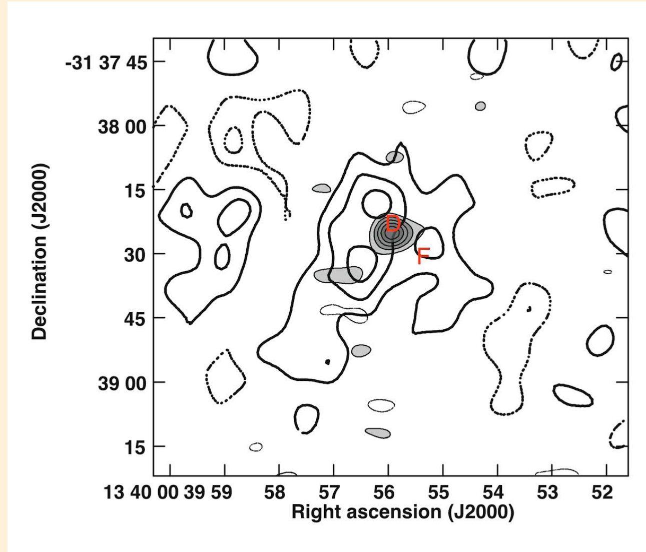

Figure 3: Dust in NGC 5253. SMA image of continuum dust emission at 870μm (greyscale), with 350μm dust continuum emission from SHARC at the Caltech Submillimeter Observatory (contours) superimposed. The SMA continuum image has been smoothed to 6" resolution to show the dust emission from the streamer. The SHARC image has been smoothed to 12.7"; contours are 2σ (σ = 3 mJy beam^{-1} at 870μm and σ = 0.2 Jy beam^{-1} at 350μm). Coordinates of the SHARC image are uncertain in absolute position to ~5" based on observations of Mars. The dust emission from Cloud F at 870μm is below the detection limit.

stars inside. A mass of gas content $M_{gas} = 7 \times 10^5 M_\odot$ is determined based on dynamical masses, implying a record star formation efficiency η > 60% [2]. This gas mass is ten times that predicted by the optically thin CO (for T=200K and Galactic [CO]/[H_2].)

The amount of dust surrounding the stars is extraordinary. The continuum image of Cloud D obtained from the SMA observations at 870μm **(Figure 3)** shows a compact dust ball with M_{gas} = 15,000 $M_\odot$. This is a high dust mass. The gas-to-dust (GTD) ratio of Cloud D is ~50, a factor of 10 below the value expected for this low metallicity ($z \sim 0.25 z_\odot$) galaxy. A mass of 30,000 $M_\odot$ in elements C, O, Mg, and Si can be produced from a super cluster with age and mass as well as metallicity that are similar to the SSC associated with Cloud D. This "chemical feedback" appears to explain the excess dust mass from the SSC with age of 3.5-4 Myr old. Yet in spite of the 7000 O stars there appears to be complete absence of dynamical feedback, since Cloud D's linewidth is that of a quiescent Galactic GMC of comparable size.

Cloud D is a strange molecular cloud: hot, dusty, and small in mass relative to its young star cluster. It is found in a dark-matter-dominated galaxy. Its unusual properties may indicate a mode of star formation different from that observed in disk galaxies, including luminous infrared galaxies. The high star formation efficiency in Cloud D might be a consequence of a streamer of gas force-fed into the star-forming region by the galactic potential. As indicated in the SMA CO (3-2) image **(Figure 2)**, a streamer coincides with the optical dust lane to the east of Cloud D. The streamer contains ~2 x 10^6 $M_\odot$ of gas extending ~200-300 pc along the minor axis, entering the galaxy at a rate of ~20 pc Myr^{-1}. The streamer can fuel star formation at the present rate of ~0.1-0.2 $M_\odot$ yr^{-1} for the next 10 million years and possibly add a new generation stars to the cluster within Cloud D.

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A *SWARM* OF *ROACHS* HAS BEEN DEPLOYED FOR SUBMILLIMETER ARRAY SCIENCE

the SWARM Development Team

The *SMA Wideband Astronomical ROACH2 Machine* (SWARM) was commissioned for SMA Science on 15 November 2014. The first installed quadrant of SWARM runs in parallel with the SMA's traditional ASIC correlator to nearly double the SMA's instantaneous bandwidth. We are presently purchasing second generation *Reconfigurable Open Architecture Computing Hardware* (ROACH2) assemblies, switches, and other equipment to build the second and third quadrants of SWARM. The second quadrant will be deployed this summer, and the third later this calendar year. In 2016 we expect four quadrants to be available, quadrupling the SMA's bandwidth to 32 GHz for both sidebands in dual polarization mode.

When running at full speed, a quadrant of SWARM either processes 2 GHz of bandwidth per polarization in full Stokes polarization mode, or 4 GHz of bandwidth from a single receiver. In November the first quadrant was running at ~54% of this bandwidth, or 6/11 mode. There are limits on the speed at which the bit code in the Field Programmable Gate Arrays (FPGAs) at the heart of SWARM may be run, and building the code to run at the necessary clock rate for full speed is difficult. In mid-May 2015 the bandwidth was increased by a further 1/3, when the 8/11 ROACH2 FPGA bit code was deployed. At time of writing, with SWARM processing 3 GHz in two 1.5 GHz chunks, in concert with the ASIC correlator's 4 GHz, an aggregate bandwidth of 7 GHz is available as standard equipment for allocated SMA science. **Table 1** lists full and 8/11 mode SWARM specifications.

Apart from bandwidth there are other key benefits of SWARM relative to the SMA's ASIC correlator:

- Higher uniform spectral resolution
- Built in VLBI phased array processor and data storage over full bandwidth
- ~10 percent better SNR due to more processed bits
- An order of magnitude smaller size and lower power consumption

Figure 1 shows 6/11 SWARM spectral line data with high uniform spectral resolution across the entire SWARM band.

Figure 2 compares continuum maps made using ASIC correlator data alone to those made with both the ASIC and SWARM 8/11 data combined. The noise level in the ASIC only map is about 40% higher than that in the combined map, consistent with expectations.

NEW BLOCK DOWN CONVERTER

A new block down converter was installed on the summit last march. The design divides the 4 – 8 GHz portion of the receiver IF into 2 blocks, 4 – 6 and 6 – 8 GHz, which are then down converted and passed to the SWARM hardware for processing. The 4 – 8 GHz BDC can process the IF from 8 receivers. A second set of hardware will be completed and installed this summer which, when combined with the existing 8 – 12 GHz down converter,

Feature	*Specification*	*8/11 mode*	*remarks*
Number of antennas	8	8	Each antenna has 2 receivers
Number of baselines	56	56	28 per receiver, full Stokes, 128 total
Bandwidth per receiver	2 GHz	1.5 GHz	Usable bandwidth, 15% guard band
Number of polarizations	2	2	DSB Rx, Walsh functions split SBs
Finest uniform resolution	140 kHz	100 kHz	2.3 or 1.67 GHz/16384 channels

Table 1: SWARM specifications showing those for the full design goal and the 8/11 mode

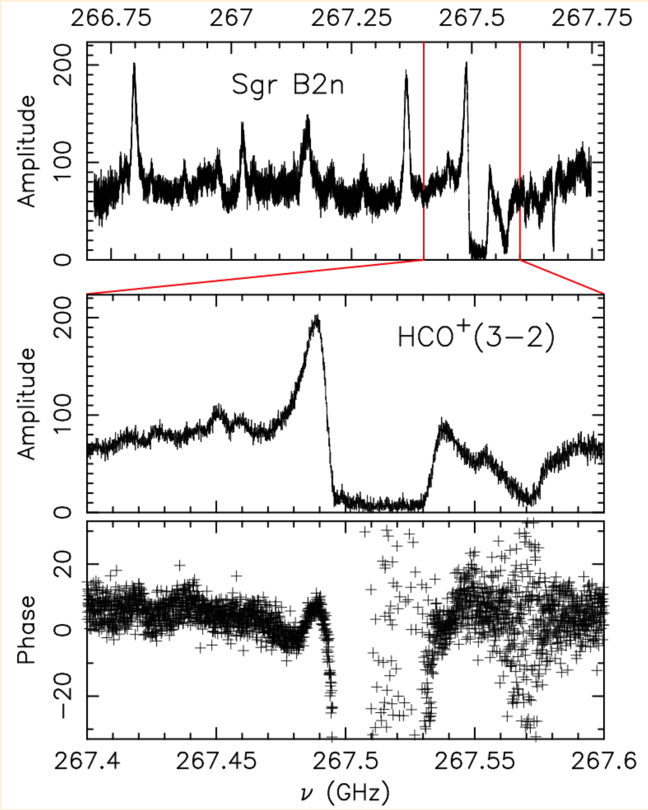


Figure 1: The HCO^+ spectral line is shown in absorption towards the source Sgr B2n. The total bandwidth of this SWARM spectrum is ~1 GHz, and the uniform spectral resolution across the full band is 70 kHz. The top plot is from one block of SWARM for a single baseline of the interferometer. The LO frequency is 278.75 GHz and the IF range is 11-12 GHz (LSB). The bottom 2 plots show the detailed HCO^+ absorption feature buried in the wide spectrum. Spectral resolution of SWARM is 70 kHz across its full band. Data reduction and calibration by Mark Gurwell. This graphic is also used in Tong et al. 2015, Proceedings of the 2015 International Microwave Symposium, IMS2015.

will give SWARM the ability to process 75% of the total receiver bandwidth from 16 wideband upgraded receivers covering the 4-12 GHz IF range in dual polarization. We expect the second quadrant of SWARM to be installed at SMA this summer and the third quadrant later this calendar year.

VLBI FIRST LIGHT: SWARM AND THE EVENT HORIZON TELESCOPE (EHT)

March 2015 saw another VLBI observing campaign at the SMA, the first to use SWARM as part of the Event Horizon Telescope. The EHT aims to image black holes with event horizon scale resolution, specifically SgrA* in the Galactic Center, the black hole in M87 in the Virgo Cluster, and NGC 5128, also known as Centaurus A. These supermassive black holes have the largest apparent Schwarzschild radius when viewed from earth. Apart from the SMA, six other observatories including JCMT, also on Mauna Kea, CARMA in California, SMT in Arizona, LMT in Mexico, IRAM 30m in Spain, and APEX in Chile participated in the EHT observation. A control room photo showing some of the EHT observational crew at SMA is shown in **Figure 3**.

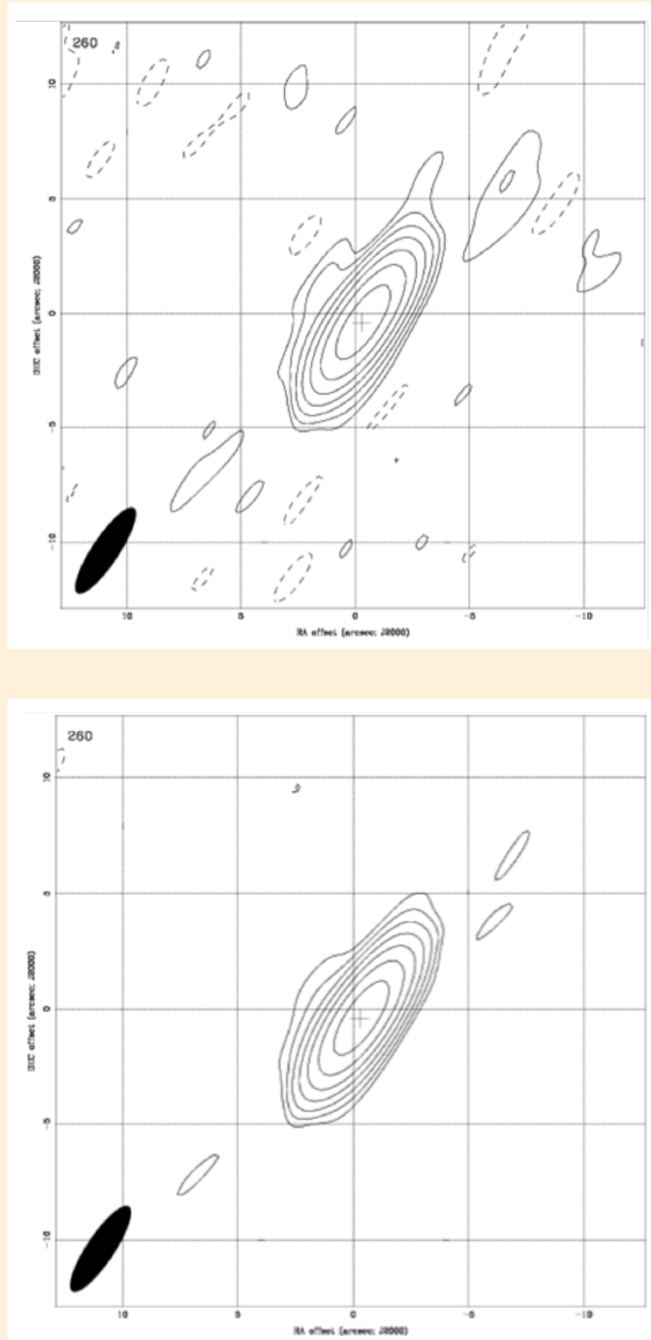


Figure 2: The above panels compare a map made using ASIC correlator data only (top panel) and ASIC+SWARM data in 8/11 bandwidth mode (bottom panel). Both images show a 20 second interval with the CLEAN component as the model, and use self-calibration. The RMS improves from 1.4 mJy (ASIC-only) to 1.0 mJy (ASIC+SWARM). These maps were made from data reduced by Charlie Qi.

SWARM data was formatted and packaged by the newly developed SWARM Digital Back End (SDBE) for capturing onto the Mark6 recorder system. Over the course of five observing nights approximately 150 TB of data was recorded at the SMA alone, at a rate of just under 10 Gbps. VLBI fringes between SWARM and LMT were found in early May 2015 at MIT Haystack Observatory, where processing and correlation of the immense amount of EHT data for 2015 is currently underway. During this campaign the SWARM Phased Array System achieved First Light for VLBI. A fringe detection between SWARM and the Large Millimeter Telescope (LMT) in Mexico is shown in **Figure 4**.

Figure 3: In the SMA Control Room, Dusan Pejakovic, Program Officer for the Gordon and Betty Moore foundation, chatted with GBMF funded postdoctoral fellow, Michael Johnson, about past EHT results, in particular horizon-scale polarization studies, a current focus. André Young and Keiichi Asada are operating the EHT Mark6 recording equipment and monitoring the observation in the background.

SWARM OPERATIONS

Operators at all three sites (Hilo, Cambridge, Taipei) have been trained on SWARM startup and operations. Transition between first and second shifts is smooth. SWARM startup has become increasingly faster as operators become more familiar with the procedure. There are some specialized observation modes (single receiver polarization; high resolution correlator mode, etc.) that are currently not SWARM compatible: notwithstanding, SWARM is utilized during nearly all standard observations

APPENDIX: SWARM VERIFICATION TESTS, AND OTHER OPERATIONAL DETAILS

This section of the article is quite technically detailed, and is provided for the benefit of SMA users who will receive SWARM data in future.

Passband Shape: Figure 5 shows the passband shape (amplitude and phase) for the older ASIC correlator's 48 chunks (color) and new SWARM chunks in 8/11 mode (black). The channels where the amplitude drops to near zero are the edge (guard) channels for each chunk. The ASIC correlator chunks are 82 MHz wide and the SWARM chunks are 1500 MHz wide. The spectral resolution of the SWARM chunks has been reduced by a factor of eight, to make its resolution match the ASIC correlators's. The 1 GHz gap between the SWARM chunks will be filled when SWARM is running at the full design speed.

Passband Stability: The SWARM passband is stable over periods as long as a typical SMA science track. **Figure 6** shows the bandpass of SWARM chunk s49 on baseline 3-4. The array was observing 3C 454.3 when this data was taken, and its bandpass was flattened using data taken 10 hours earlier on 3C 279.

ASIC vs SWARM phase tracking: In order to be able to take full advantage from the additional bandwidth provided by SWARM, we need to be able to add its signal to that of the ASIC correlator before performing complex gain calibration, so that weak calibrators near the science target have improved SNR. For this to be possible, SWARM must be phase stable with respect to the ASIC correlator. **Figure 7** shows that this condition is met.

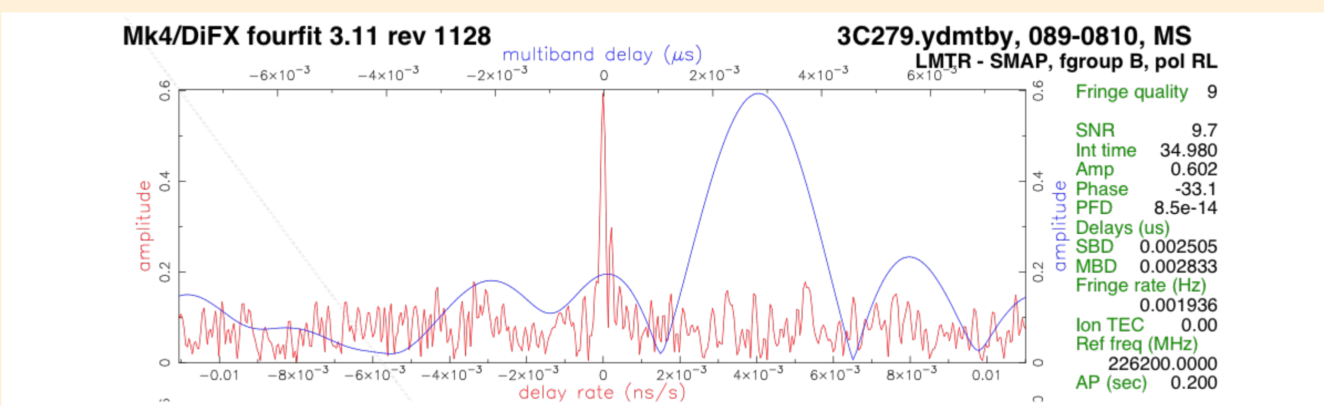


Figure 4: A 1.3 mm VLBI fringe detection on the quasar 3C279 on a transcontinental baseline between SMA's SWARM phased array and the Large Millimeter Telescope (LMT). These data were taken on 28 March 2015 and represents the Event Horizon Telescope's First Light for SWARM. In VLBI one searches for correlation in a two dimensional space, with the two parameters being a. the geometric delay and b. the delay rate. The latter is equivalent to what is usually termed fringe rate. The blue curve shows a cut in the correlation surface parallel to the delay axis, and the red curve is a slice parallel to the delay-rate. Both slices pass through the correlation peak.

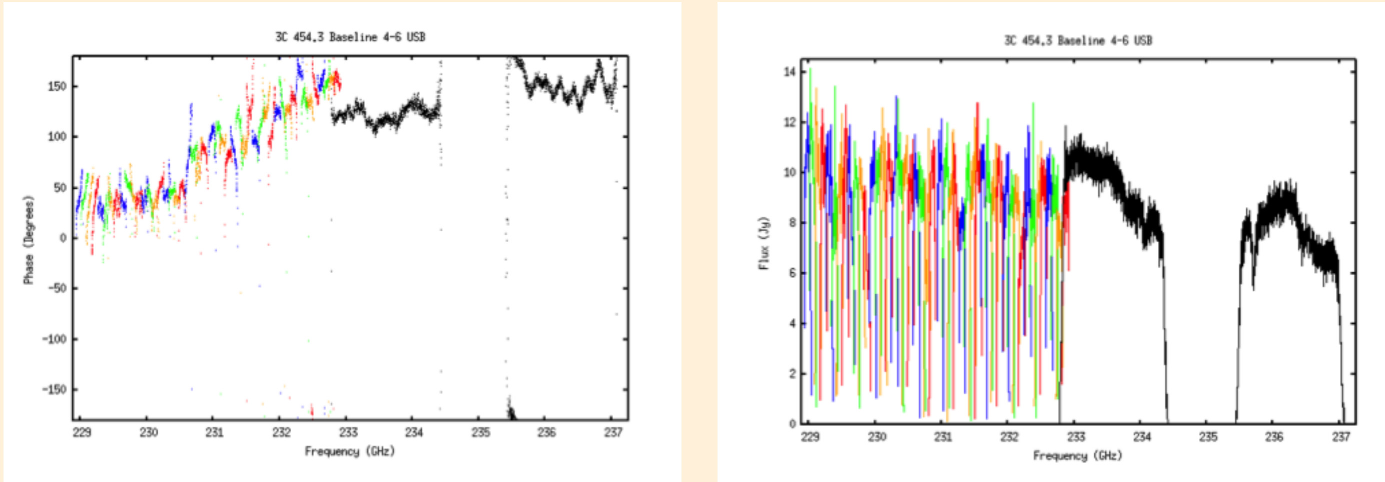


Figure 5: SWARM Passband Shape Verification

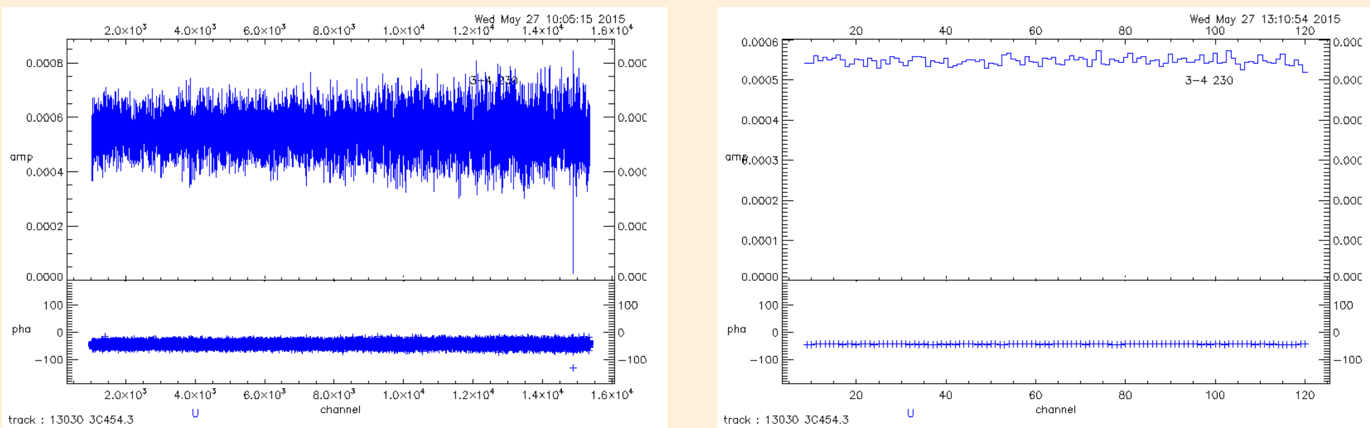


Figure 6: SWARM Passband Stability Verification. The left plot shows the full spectral resolution, and the right shows the same data, vector averaged in sets of 128 channels. The flatness of the amplitude and phase confirms that the bandpass does not change shape during an observation.

Spectral observations: The portion of the IF processed by the ASIC correlator is adjustable, and it is possible to make the ASIC correlator and SWARM process the same portion of the IF so that the spectral response of the two correlators can be compared. **Figure 8** shows this comparison.

ASIC compared to SWARM Signal-to-Noise-Ratio (SNR): After calibration, the SNR of the SWARM spectral line detection of the SiO(5-4)(v=1) line is 9.6% higher than the ASIC correlator detection. Because the ASIC correlator is a “modified 2 bit correlator”, its SNR should be 15% lower than a perfect correlator would produce. SWARM uses an 8 bit sampler, and appears to recover much of the sensitivity lost due to the ASIC low dynamic range sampling.

Software Accommodations: The ASIC correlator is only able to produce high spectral resolution over a portion of the IF it is processing. This means that the PI of a project must select a correlator configuration during the proposal process. In contrast, SWARM produces high spectral resolution throughout its bandpass, and the PI does not need to specify any configuration information about it in the project proposal.

One side effect of this is that the science data sets produced with SWARM often have far higher spectral resolution than the project needs. Calibration and imaging of such a large data set can be slow, and requires a computer with a lot of RAM. If the science goal of the project requires only continuum processing the SWARM data at full resolution is needlessly time consuming. To facilitate data reduction for projects which do not require SWARM's full spectral resolution, both the MIR/IDL package and the sma2casa.py script (which allows SMA data to be imported to CASA) allow new spectral bands to be defined which will contain only a subset of the SWARM bandwidth, or reduced spectral resolution. This allows the PI, at the data reduction stage, to “reconfigure” SWARM to have high resolution in portions of the spectrum with important line features, and coarse resolution where only the continuum flux is of interest.

Some quirks of SWARM: A tunable YIG oscillator is used to provide a reference frequency for the gunn oscillator PLL. This YIG

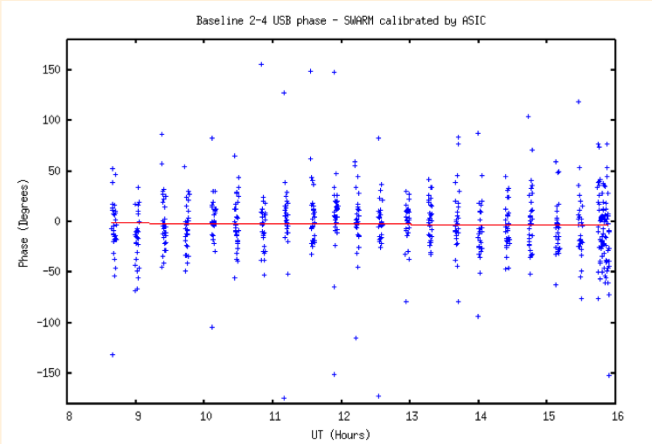


Figure 7: SWARM phase of NRAO 530 (1.4 Jy at 230 GHz) over time, after phase calibration using the ASIC correlator data. If SWARM is phase-stable relative to the ASIC correlator, we would expect the phase in this plot to be constant. The blue crosses show the individual scan phases, and the red line is the linear least squares best fit. The slope of the line is only 0.28 degrees per hour, showing that SWARM tracks the ASIC correlator phase very well.

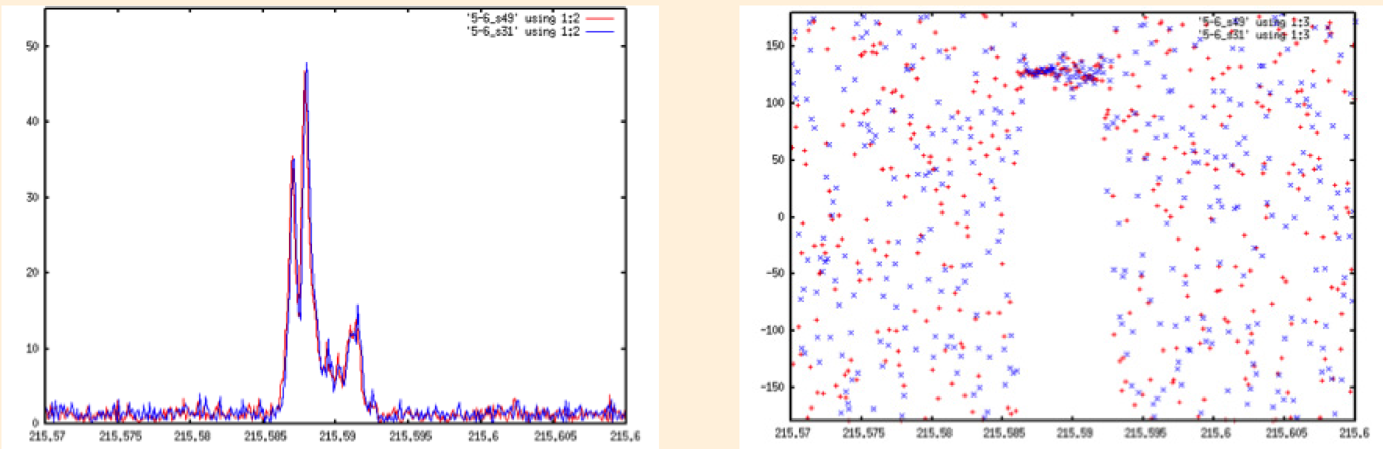


Figure 8: When averaged over all baselines, the total calibrated flux show the SiO(5-4)(v=1) maser line in R Cas processed by both the ASIC correlator (red) and SWARM (blue). The spectral resolution of SWARM has been reduced by a factor of 8, to match the ASIC correlator's resolution. The integrated intensity in the SiO(5-4)(v=1) line differs by less than 1% for the two systems.

can be tuned from 6 to 9.5 GHz. With the addition of SWARM, all of the IF from 4 to 9.5 GHz is being correlated, and the YIG signal is clearly seen as an interference spike in the spectra. For any desired Gunn frequency, there are usually several YIG frequencies which can be used to lock the Gunn (utilizing different Gunn PLL harmonics). We have found that if the YIG frequency falls within the ASIC correlator's portion of the IF, one or two ASIC correlator chunks (each 82 MHz wide) are usually completely corrupted. If the YIG frequency falls within SWARM's portion of the IF, as little as one MHz of the spectrum is corrupted. So it will usually be preferable to select a YIG frequency that falls within the SWARM region of the IF (8 to 9.5 GHz). The SMA Passband Visualizer (http://sma1.sma.hawaii.edu/smaPassbandViewer/smaPassbandVis.html) can be used to see where the YIG spike will fall within your spectrum, allowing you to avoid having it interfere with a spectral feature that is important to your project. The MIR/IDL package allows the interference spike to be "removed", by substituting the interpolated value from adjacent channels for the value in the channel showing the YIG interference. Efforts to suppress the YIG interference in hardware are ongoing.

Now that we are processing 14 GHz of the IF (counting both sidebands) which differ by 24 GHz in sky frequency at the extremes, the system temperature is apt to vary considerably over our spectra, due to both the non-uniform sky opacity, and the rolloff of our receivers near their high frequency limits. To properly weight the data, we need to know how T_{sys} varies as a function of frequency in our IF. A new continuum system, allowing T_{sys} to be measured every 1 GHz throughout the IF is being deployed, but we are not currently measuring T_{sys} above 8 GHz in the IF. This means that we cannot yet assign the correct T_{sys} to the SWARM chunks. This has two effects: the conversion of correlation coefficients to uncalibrated flux is less accurate for the SWARM chunks, and if T_{sys} weighting is used for producing maps, the SWARM chunks will not be assigned the optimal weights. This second weighting problem can be overcome if the data are gain calibrated using the MIR/IDL software package.

SECURING SERVICE-AVAILABILITY IN HAWAII USING VIRTUAL INFRASTRUCTURE

Thomas Cooper (CfA)

Maintaining service-availability is key to keeping the telescope operational. To operate a telescope such as the SMA, we need reliable services for storing data, displaying data, and controlling the telescope.

Cloud computing is one strategy to provide the services that are needed by the SMA. The federal government has now embraced a "cloud first" strategy, but many of the services that are required by the SMA are not practical in a public cloud strategy, as they require a much tighter coupling between the clients and service providers. Our virtual infrastructure is similar to cloud computing in that it allows the service providers, which are virtual machines that mimic servers in the traditional sense, to migrate among several physical servers. This strategy improves reliability, flexibility, and disaster recovery. We are enhancing the capability in the Cambridge control room this summer as an extension of the virtual infrastructure philosophy. While this extension is probably not generally useful to control the telescope, it will provide a useful environment for software development and test, and will provide an additional site for disaster recovery outside of Hawaii.

Storage virtualization means decoupling disk storage from specific servers. All SMA summit primary storage is now provided by iSCSI storage systems. Internet Protocol (IP) networks provide the glue to connect all the virtualized storage and services to each other and ultimately to the end

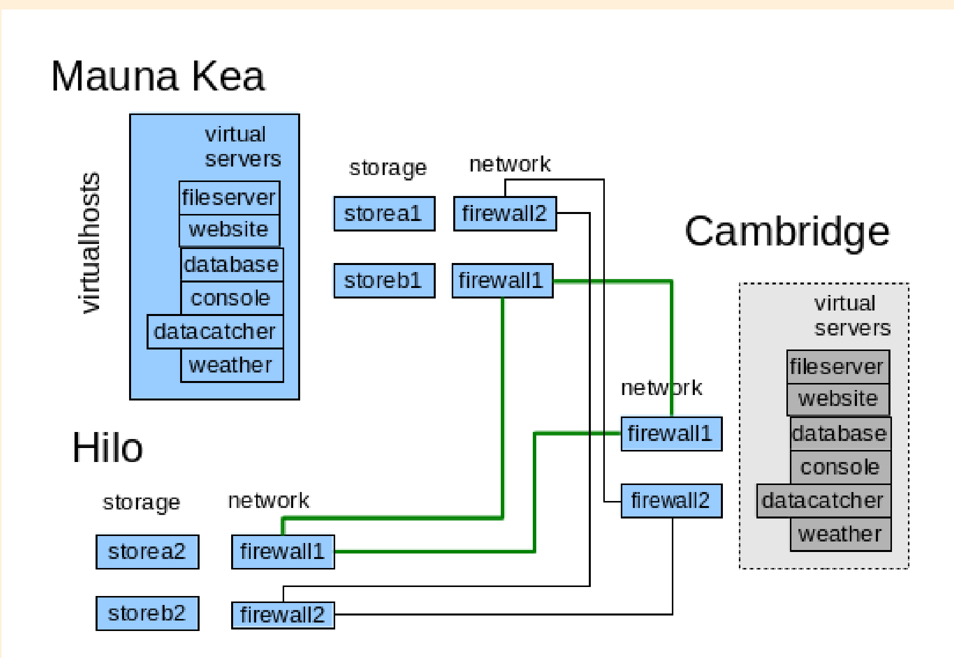


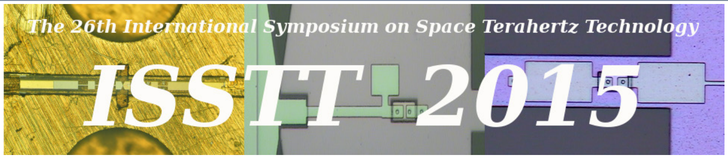
Figure 1: Infrastructure overview showing network redundancy and anticipated extension to Cambridge.

users. Therefore network redundancy is essential for reliability.

Here are just a few details regarding six of the services provided by our virtual infrastructure. We have triple redundant virtual machine hosts that can run all the essential virtual machine servers and thus provide services to operate the array.

- The tftp and rarpd services allow us to boot all of our diskless computer nodes, such as antenna control computers, ASIC correlator computers, the polarization control computers, and all the ROACHes in the SWARM correlator.
- The https secure service provided by an apache web server allows us to run the SMA observer center (SMAOC) and provide the project proposal database and other essential services for the time allocation committee (TAC). The SMAOC also provides the primary user interface and tools for our science and engineering user community to view and plot engineering data, create proposals, and create observing plans.
- The database service is provided by Postgres SQL server, and is the primary repository for all engineering data related to the array.
- There are also workstation virtual machines and one of those provides our primary observing console service for the real-time operation and monitoring of the array on public and private networks.
- Our dataCatcher service receives and then writes all of our science data from the correlators to storage.
- The file server NFS service provides all the shared files needed by workstations and servers throughout the SMA organization.

THE 26TH INTERNATIONAL SYMPOSIUM ON SPACE TERAHERTZ TECHNOLOGY



The Smithsonian Astrophysical Observatory and the Harvard College Observatory were hosts to ISSTT-2015, which was held at Harvard's Knafel Center from March 16th through March 18th. Staff members from SAO's Submillimeter Array and Harvard's Cosmic Microwave Background group formed the core of the local organizing committee.

The main focus of the symposium was on millimeter, submillimeter, and THz technology and its applications. More than 130 registered participants from over a dozen countries enjoyed the opportunity to catch up and exchange new ideas. Half of the 92 accepted submissions for presentation at the symposium were arranged into 10 oral sessions, which focused on: Systems for Space Applications, Hot Electron Bolometers, Receivers, Bolometric Spectrometers, Sources, Quantum Cascade Lasers, CMB Instrumentation, Detection Theory and Techniques, and Direct Detectors. The remaining 46 were allocated space for presentation in a single poster session, which was well attended.

Of particular interest was a special session: 'History and Current Developments', in which four invited speakers – Bob Wilson, Alan Rogers, Sandy Weinreb, and Jonas Zmuidzinus – captivated the audience with their respective presentations: 'The Discovery of Interstellar CO', 'Discoveries and Technical Developments in VLBI', 'Radio Astronomy – Past, Present, and Future', and 'Superconducting Detectors and Mixers: A Brief History'. Another symposium highlight was the lab tour, in which about 100 enthusiastic symposium participants crammed into SAO's Submillimeter Receiver Lab and Harvard's CMB Lab.

The proceedings for the symposium are available at:

https://www.cfa.harvard.edu/isstt2015/

Proceedings from previous symposia can be found at:

www.space-thz.org

Ray Blundell and Edward Tong

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 Summer/Fall 2016. 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 own research activities.

Applicants must have a recent PhD in astronomy or a related field. Experience in millimeter or submillimeter astronomy, radio interferometry, radio frequency instrumentation, and/or research in processes in the interstellar medium is desirable.

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:

https://www.cfa.harvard.edu/opportunities/fellowships/sma/

Questions can be directed to:

smapostdoc@cfa.harvard.edu

Online applications are due Friday, October 30, 2015.

NEW SMA POSTDOCTORAL FELLOWS FOR 2015

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, who will arrive in fall 2015:

Shaye Storm will be joining us after completion later this summer of his Ph.D. work at the University of Maryland (Advisor: Prof. Lee G. Mundy). His thesis work focuses on connecting cloud-to-core scales with large-area, high angular resolution spectral imaging of nearby molecular clouds, through the CARMA Large Area Star Formation Survey (CLASSy) Key Project. Dr. Storm co-developed this project, managed the 700 hours of CARMA observations, led the data calibration and production of science-ready data cubes, and developed new software for analysis of cloud structure.

Junko Ueda will be returning this fall to the CfA, where she was in residence as an SAO Predoctoral Fellow from Sep 2011-March 2013. Dr. Ueda received her Ph.D. in 2014 from the University of Tokyo (Advisor: Prof. Ryohei Kawabe), after defending her thesis work 'Molecular Gas in Late-stage Merging Galaxies'. This research emphasized mm/submm observations of cold molecular gas in colliding galaxies to study galaxy formation and evolution, which included SMA observations of several systems including the Antennae galaxies. From April-October 2014 she served as a Japan Society for the Promotion of Science (JSPS) Postdoctoral Research Fellow with the National Astronomical Observatory of Japan and became a NAOJ Project Research Fellow at the East Asia-ALMA Research Center (EA-ARC) in November 2014.

In addition, we welcome:

L.Ilsedore (Ilse) Cleeves will begin her Hubble Postdoctoral Fellowship here at the CfA starting in the fall, including association with the Submillimeter Array and the CfA Institute for Theory and Computation. She has been a Rackham Predoctoral Fellow while completing her Ph.D. at the University of Michigan (Advisor: Dr. Edwin A. Bergin). Her research focuses on understanding the molecular and physical origins of planetary systems: using clues from interstellar molecular emission, guided in part by observational results from the

Submillimeter Array as well as the Herschel Space Observatory, she studies young planetary systems in formation around low-mass stars. Her Ph.D. thesis focuses on the chemical and physical consequences of high energy processes, such as ionization, in protoplanetary disks.

The incoming postdoctoral fellows join current SMA Fellows **Lars Kristensen, Cara Battersby, Michael Dunham,** and **Luca Ricci**. 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. The deadline for application for the 2016 SMA Fellowship opportunity will be October 30, 2015.

Mark A. Gurwell
Chair, SMA Fellowship Selection Committee

CALL FOR SMA SCIENCE OBSERVING PROPOSALS

The joint CfA-ASIAA SMA Time Allocation Committee (TAC) solicits proposals for observations for the period November 16, 2015 - May 15, 2016 (2015B semester). The deadline for submitting proposals is August 4, 2015.

For more information please see link below.

http://sma1.sma.hawaii.edu/proposing.html

The deadline for the following semester (May 16, 2016 - Nov 15, 2016) is expected to be in February, 2016.

PROPOSAL STATISTICS 2015A (16 MAY 2015 – 15 NOVEMBER 2015)

The SMA received a total of 83 proposals (SAO 62) requesting observing time in the 2015A semester. The proposals received by the joint SAO and ASIAA Time Allocation Committee are divided among science categories as follows:

Category	Proposals
low/intermediate mass star formation, cores	24
high mass (OB) star formation, cores	19
protoplanetary, transition, debris disks	10
local galaxies, starbursts, AGN	9
submm/hi-z galaxies	6
evolved stars, AGB, PPN	4
GRB, SN, high energy	3
other	3
UH	3
galactic center	1
solar system	1

TRACK ALLOCATIONS BY WEATHER REQUIREMENT (ALL PARTNERS):

PWV[1]	SAO	ASIAA	UH[2]
< 4.0mm	9A + 11B	10A + 8B	8
< 2.5mm	19A + 14B	0A + 3B	14
< 1.0mm	2A + 0B	0A + 1B	0
Total	**30A + 25B**	**10A + 12B**	**22**

(1) Precipitable water vapor required for the observations.

(2) UH does not list As and Bs.

TOP-RANKED SAO AND ASIAA PROPOSALS – 2015A 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.

GRB, SN, HIGH ENERGY

Atish Kamble, Harvard-Smithsonian Center for Astrophysics
The Unprecedented Metamorphosis of Supernova 2014C: from a Hydrogen-stripped to a Strongly Interacting Supernova

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 fragmention

Qizhou Zhang, CfA
Role of Magnetic Fields in the Early Phase of Massive Star Formation

R.M. Crutcher, UIUC
CN Zeeman Mapping of Magnetic Field Strengths

LOCAL GALAXIES, STARBURSTS, AGN

Geoffrey Bower, ASIAA
Variability Timescale of Low Luminosity AGN

Wen-Ping Lo, ASIAA
Mass Accretion Rate onto the SMBH of Cyg A with mm/submm polarimetry

LOW/INTERMEDIATE MASS STAR FORMATION, CORES

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

Hsi-Wei Yen, ASIAA
From Large-Scale Gas Motions to Star Formation in Individual Dense Cores in L1455

Hsi-Wei Yen, ASIAA
Testing Magnetic Braking in the Class 0 Protostar B335

Ian Stephens, Boston University
Mapping Line Polarization in L1157

Lars Kristensen, Harvard-Smithsonian Center for Astrophysics
Hot water with the SMA: a unique view of disks and winds in embedded low-mass protostars

Shaye Storm, University of Maryland
Kinematic Signatures of Filament Formation: In Search of Gradients

OTHER

Michael McCollough, Smithsonian Astrophysical Observatory
Monitoring A Major Cygnus X-3 Flare (copied from 2014A-S048)

PROTOPLANETARY, TRANSITION, DEBRIS DISKS

Charlie Qi, CfA
A search for the CO snow line in the HL Tau disk

Joel Kastner, Center for Imaging Science, Rochester Institute of Technology
Imaging Molecular Emission Rings in Nearby Protoplanetary Disks

Kate Su, University of Arizona; ASIAA
Searching for Cold Dust around Extreme Debris Disks -- Sites for Active Terrestrial Planet Building/Destruction

Luca Ricci, CfA
A Census of Circumstellar Disks in Ophiuchus

SUBMM/HI-Z GALAXIES

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

Scott Chapman, Dalhousie University
[CII] in z~5 SMGs from the Herschel-red ALMA survey

ALL SAO PROPOSALS - 2014B SEMESTER

The following is the listing of all SAO proposals observed in the 2014B semester (16 Nov 2014 - 15 May 2015)

Sean Andrews, CfA
A Size--Luminosity Scaling for Protoplanetary Dust Disks

Keiichi Asada, ASIAA
Mass Accretion Rate onto the SMBH of nearby Radio Galaxies with mm/submm polarimetry

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

Vivien Huei-Ru Chen, National Tsing Hua University
Exploring Interactions between Magnetic Fields and Massive Young Stellar Objects

You-Hua Chu, ASIAA
Dust Shell Formation around the Central Star of the Planetary Nebula NGC2346

Sheperd Doeleman, SAO
Polarimetric VLBI with the Event Horizon Telescope

Michael Dunham, CfA
Astro 191: Molecular outflow and core rotation around protostars

Giovanni G. Fazio, CfA
A Search for [CII] in an Exceptionally Bright LBG Galaxy in the Era of Reionization (z=6.76)

Nanase Harada, ASIAA
Distribution of Molecular Tracers in Starburst Galaxies

Jun Hashimoto, Astrobiology Center, National Institutes of Natural Sciences
Potential Dust Trap in Asymmetric Transitional disks

Naomi Hirano, ASIAA
Magnetic fields in the earliest stage of low-mass star formation

Naomi Hirano, ASIAA
Spatio-Kinematic Structure of the HH 114 MMS outflow

Todd Hunter, NRAO
Imaging the Proto-B-Star G34.24+0.13MM: Has L_bol/M_gas=30 and Sigma=3g/cm^2 suppressed further fragmentation?

Chien-De Lee, Institute of Astronomy National Central University
Dust Formation in Evolved Massive Main Sequence Stars --- Resolving the Disk Structure in the Classical Be Star FS CMa

Hau-Yu Baobab Liu, ASIAA
Evidences for the Dustless Unstable Disks?

Xing Lu, CfA
Massive star formation in progress in filamentary clouds

Meredith MacGregor, Harvard University
Structure of the HD 32297 Debris Disk

Nicole Nesvadba, Institut d'Astrophysique Spatiale Orsay (France)
Zooming in onto star formation in the brightest gravitationally lensed galaxies from the Planck all-sky survey

Charlie Qi, CfA
A search for the CO snow line in the HL Tau disk

Luca Ricci, CfA
A Census of Circumstellar Disks in Ophiuchus

Raghvendra Sahai, Jet Propulsion Laboratory
Investigating Circumstellar Gravel in Dying Stars

Alberto Sanna, Max-Planck-Institut fuer Radioastronomie
Confirming a Keplerian disk around an O-type star

Howard Smith, CfA
Simultaneous Sgr A Observations with Megellan, Keck and Chandra*

T.K. Sridharan, CfA
Magnetic Fields, Rotating Pseudo-disk and Chemical Segregation in W43-MM1

Srikar Srinath, U.C. Santa Cruz
Mapping molecular outflows in LIRGs

Ian Stephens, Boston University
Mapping Line Polarization in L1527

Shigehisa Takakuwa, ASIAA
Circumbinary Rings and Mass Accretion onto Protostellar Binary Systems

Shigehisa Takakuwa, ASIAA
Transition from the Infalling Envelope to the Planet-Forming Disk in HL Tau Revealed with the SMA

Yuan Wang, University of Geneva
Investigating the sequential star formation in S235 complex

Steven Willner, CfA
Confirming the z = 1.5 Cluster around 3C270.1 by Gravitational Lensing of a Background z = 4.9 SMG

David Wilner, CfA
Search for Cometary Molecules in the beta Pictoris Debris DIsk

RECENT PUBLICATIONS

Title: Sub-mm Jet Properties of the X-Ray Binary Swift J1745-26
Authors: Tetarenko, A. J.; Sivakoff, G. R.; Miller-Jones, J. C. A.; Curran, P. A.; Russell, T. D.; Coulson, I. M.; Heinz, S.; Maitra, D.; Markoff, S. B.; Migliari, S.; Petitpas, G. R.; Rupen, M. P.; Rushton, A. P.; Russell, D. M.; Sarazin, C. L.
Publication: *eprint arXiv:1502.00039*
Publication Date: 01/2015
Abstract: http://adsabs.harvard.edu/abs/2015arXiv150200039T

Title: Resolving the Bright HCN(1-0) Emission toward the Seyfert 2 Nucleus of M51: Shock Enhancement by Radio Jets and Weak Masing by Infrared Pumping?
Authors: Matsushita, Satoki; Trung, Dinh-V.-; Boone, Frédéric ; Krips, Melanie; Lim, Jeremy; Muller, Sebastien
Publication: *The Astrophysical Journal, Volume 799, Issue 1, article id. 26, 10 pp. (2015). (ApJ Homepage)*
Publication Date: 01/2015
Abstract: http://adsabs.harvard.edu/abs/2014arXiv1410.7863M

Title: Six Years of Fermi-LAT and Multi-Wavelength Monitoring of the Broad-Line Radio Galaxy 3c 120: Jet Dissipation At Sub-Parsec Scales from the Central Engine
Authors: Tanaka, Y. T.; Doi, A.; Inoue, Y.; Cheung, C. C.; Stawarz, L.; Fukazawa, Y.; Gurwell, M. A.; Tahara, M.; Kataoka, J.; Itoh, R.
Publication: *The Astrophysical Journal Letters, Volume 799, Issue 2, article id. L18, 6 pp. (2015). (ApJL Homepage)*
Publication Date: 02/2015
Abstract: http://adsabs.harvard.edu/abs/2015ApJ...799L..18T

Title: Rapid Variability of Blazar 3C 279 during Flaring States in 2013-2014 with Joint Fermi-LAT, NuSTAR, Swift, and Ground-Based Multi-wavelength Observations
Authors: Hayashida, M.; Nalewajko, K.; Madejski, G. M.; Sikora, M.; Itoh, R.; Ajello, M.; Blandford, R. D.; Buson, S.; Chiang, J.; Fukazawa, Y.; Furniss, A. K.; Urry, C. M.; Hasan, I.; Harrison, F. A.; Alexander, D. M.; Balokovic, M.; Barret, D.; Boggs, S. E.; Christensen, F. E.; Craig, W. W.; Forster, K.; Giommi, P.; Grefenstette, B.; Hailey, C.; Hornstrup, A.; Kitaguchi, T.; Koglin, J. E.; Madsen, K. K.; Mao, P. H.; Miyasaka, H.; Mori, K.; Perri, M.; Pivovaroff, M. J.; Puccetti, S.; Rana, V.; Stern, D.; Tagliaferri, G.; Westergaard, N. J.; Zhang, W. W.; Zoglauer, A.; Gurwell, M. A.; Uemura, M.; Akitaya, H.; Kawabata, K. S.; Kawaguch, K.; Kanda, Y.; Moritani, Y.; Takaki, K.; Ui, T.; Yoshida, M.; Agarwal, A.; Gupta, A. C.
Publication: *eprint arXiv:1502.04699*
Publication Date: 02/2015
Abstract: http://adsabs.harvard.edu/abs/2015arXiv150204699H

Title: Observations of Infalling and Rotational Motions on a 1000 AU Scale around 17 Class 0 and 0/I Protostars: Hints of Disk Growth and Magnetic Braking?
Authors: Yen, Hsi-Wei; Koch, Patrick M.; Takakuwa, Shigehisa; Ho, Paul T. P.; Ohashi, Nagayoshi; Tang, Ya-Wen
Publication: *The Astrophysical Journal, Volume 799, Issue 2, article id. 193, 26 pp. (2015). (ApJ Homepage)*
Publication Date: 02/2015
Abstract: http://adsabs.harvard.edu/abs/2015ApJ...799..193Y

Title: Constraining the X-Ray and Cosmic-Ray Ionization Chemistry of the TW Hya Protoplanetary Disk: Evidence for a Sub-interstellar Cosmic-Ray Rate
Authors: Cleeves, L. Ilsedore; Bergin, Edwin A.; Qi, Chunhua; Adams, Fred C.; Öberg, Karin I.
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Authors: Thomson, A. P.; Ivison, R. J.; Owen, Frazer N.; Danielson, A. L. R.; Swinbank, A. M.; Smail, Ian
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