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SMA Newsletter

Submillimeter Array Newsletter | Number 24 | July 2017

CONTENTS

1 From the Director

SCIENCE HIGHLIGHTS:

2 An Extraordinary Outburst in the Massive Protostellar System NGC6334I-MM1: Quadrupling of the Millimeter Continuum

5 Cygnus X-3: Its Little Friend's Counterpart, the Distance to Cygnus X-3 and Outflows/Jets

7 The Galactic Center Molecular Cloud Survey: A First View with the SMA

10 The *Herschel*-ATLAS: a sample of 500 μm-selected strongly lensed galaxies over 600 deg^2

TECHNICAL HIGHLIGHTS:

14 Science With the Wideband SMA: A Strategy for the Decade of 2017-2027

15 SMA Was a Key Station in the 2017 Event Horizon Telescope Observing Campaign

OTHER NEWS

17 Eric Keto Retires

18 Staff Changes in Hilo

SMA Postdoctoral Fellows: Comings and Goings

19 Postdoctoral Opportunities With the SMA

Call For Proposals

20 Proposal Statistics

Track Allocations

21 Top-Ranked Proposals

22 All Proposals

24 Recent Publications

FROM THE DIRECTOR

Dear SMA Newsletter readers,

The success of the recent call for proposals issued by ALMA to observe using ten 7-meter antennas of the compact array, in a stand-alone observing mode, underscores the upsurge in community interest in interferometric observations having lower sensitivity and imaging capability than that offered by the full ALMA array. Recent upgrades to the SMA, including the successful deployment of the SWARM correlator, have made it possible to make observations in either dual polarization or dual band mode with a maximum processed bandwidth totaling 32 GHz. This represents a significant improvement in performance, and brings the SMA sensitivity to within a factor of two of the ALMA compact array for continuum observations in the 230 GHz frequency band. Furthermore, with multiple configurations possible, the SMA offers good imaging capability up to moderate angular resolution and is complementary to the ALMA compact array in ALMA bands 6 and 7, especially for targets in the northern part of the sky.

I encourage you to visit the SMA website for details of array performance and the upcoming SMA call for proposals. I would also like to call your attention to the recently updated procedure for proposing large-scale projects, which can be found there as well.

Ray Blundell

AN EXTRAORDINARY OUTBURST IN THE MASSIVE PROTOSTELLAR SYSTEM NGC6334I-MM1: QUADRUPLING OF THE MILLIMETER CONTINUUM

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The phenomenon of episodic accretion is increasingly recognized as being essential to star formation (Kenyon et al. 1990; Evans et al. 2009). FU Ori stars represent the classical manifestation of such events (Hartmann & Kenyon 1996) in which a protostar's luminosity rises rapidly by a factor of ~100. It typically decays slowly over tens to perhaps a few 100 years (Audard et al. 2014), during which time an elevated quasi-steady accretion rate can persist (e.g., Zhu et al. 2010). As infrared surveys have matured, similar outbursts in younger protostars have been identified. Recently, Safron et al. (2015) identified the first outburst in a Class 0 protostar (HOPS 383), which is a low-mass (0.2 $M_\odot$) object that increased in luminosity by a factor of 30-50 in less than 18 months. Single dish measurements of submillimeter continuum revealed an accompanying factor of ~2 increase attributed to re-processed dust emission from the heated protostellar cocoon. Radiative transfer simulations show that dust emission will respond to an outburst in a matter of weeks to months (Johnstone et al. 2013), and a systematic search for more such events in nearby clusters is currently underway at the JCMT (Mairs et al. 2017).

It is likely that high mass protostars also undergo accretion outbursts, and they may even happen more frequently than in low mass protostars given their relatively shorter evolutionary timescale. Due to the deeply-embedded nature of massive protostars, the (sub)millimeter regime provides a distinct advantage for identifying outbursts because it can probe objects located within much higher column densities. Massive protostars seem to form in compact clusters, called "protoclusters", on scales similar to the Orion Trapezium stars (10,000 AU). Due to the typically large (> 1kpc) distances to these systems, interferometers with sub-arcsecond resolution like the SMA are essential for studying their individual protostars. Beginning with SMA observations in 2004-2005, we resolved the protocluster NGC6334I with 1.5″ resolution (2000 au) into four sources at 1.3 mm: the well-known ultracompact (UC) HII region (MM3=NGC6334F), two line-rich hot cores (MM1 & MM2), and a warm dust core MM4 (Hunter et al. 2006). The latter three objects are deeply embedded and remain undetected at infrared wavelengths at least as long as 18μm (De Buizer et al. 2002). Recently, we observed NGC6334I with the Atacama Large Millimeter/submillimeter Array (ALMA) in Cycle 2 with an angular resolution of 0.17″ (220 au) at 1.3 mm. The continuum from the hot core MM1 was resolved into seven components within a projected radius of 1000 au, with brightness temperatures ranging from 100 K to 260 K indicating minimum luminosities of order 10^4 $L_\odot$ (Brogan et al. 2016). Thus, ALMA's initial view of NGC6334I MM1 suggested a "hot multi-core" of gas and dust heated by multiple massive protostars undergoing accretion. However, when combined with VLA data from 2011, the 1.5 cm to 1.3 mm spectral energy distributions were anomalously steep for several components of MM1, prompting a detailed comparison with the most recent SMA observations at 1.3 and 0.87 mm.

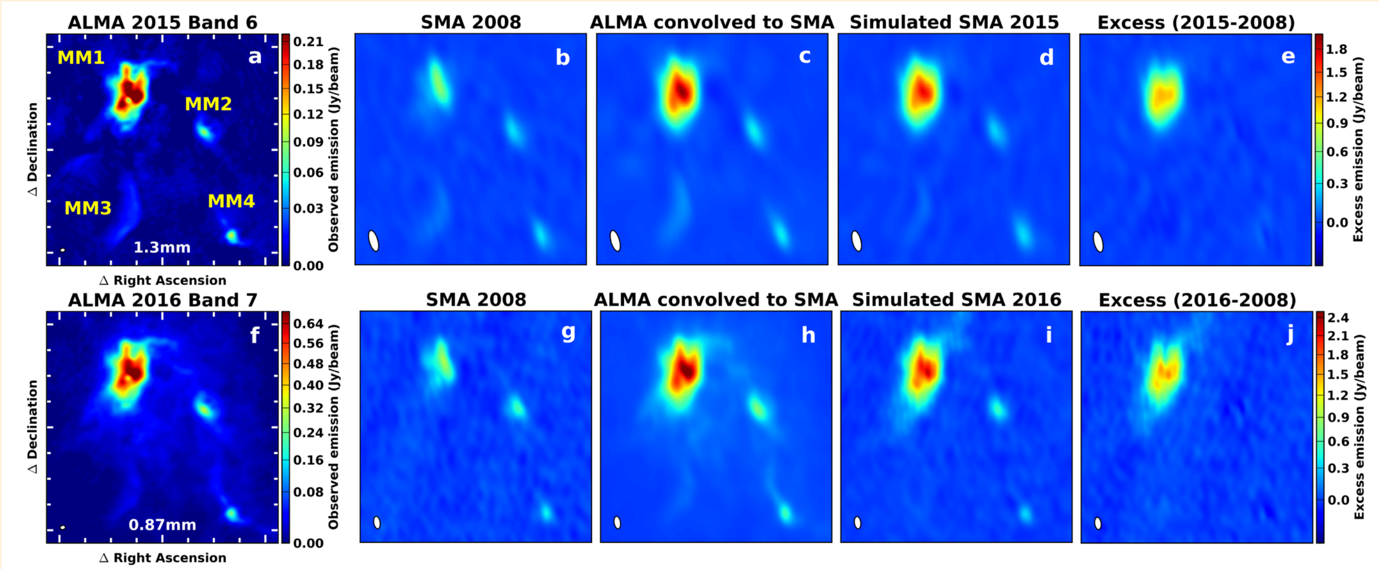

Figure 1: (a) ALMA 1.3 mm continuum observed in 2015 August (0.20″ x 0.15″ beam, Brogan et al. 2016); **(b)** SMA 1.3 mm continuum observed in 2008 August (0.84′′x0.33′′ beam); **(c)** ALMA image convolved to the SMA beam; **(d)** CASA simulation using the exact uv-coverage of panel (b) to observe the sky model of panel **(a)**; **(e)** the simulated SMA image minus the observed SMA image, revealing the large emission excess from MM1 and insignificant change in the other three sources (MM2, MM3, MM4), confirming a robust flux calibration. Field of view is 9 arcseconds. Panels **f-j** show the same analysis at 0.87 mm. Panels b-e and g-j are shown on a common intensity scale.

The ALMA 1.3 mm image (**Fig. 1a**) is shown alongside the SMA image observed seven years earlier in the very extended configuration (**Fig. 1b**). Convolving the ALMA image to the resolution of the SMA image, the result (**Fig. 1c**) shows a surprising difference in the morphology and the total flux density of MM1 (10.8 vs. 2.34 Jy) between the two epochs. Residual line emission contaminating the channels chosen to form the ALMA continuum image cannot be the cause of such a large difference in flux density. Furthermore, the spectrum of the MM2 hot core is similarly line-rich (Zernickel et al. 2012) so any line contamination effect should manifest in that source as well. To exclude uv-sampling effects as the culprit, we simulated the 2008 SMA observations using the 2015 ALMA 1.3 mm image (Fig 1a) as the sky model and applying the identical uv-coverage and flagging of our 2008 SMA observations (**Fig. 1b**). The resulting image (**Fig. 1d**) demonstrates what the SMA would have seen had it observed the region simultaneously with ALMA in 2015. SMA could have recovered 87% (9.4 Jy) of the MM1 emission found by ALMA, meaning that the bulk of the difference between the 2008 and 2015 images cannot be due to uv-sampling. Furthermore, **Fig. 1e**, which shows the difference between the simulated 2015 SMA image and the actual 2008 SMA image, demonstrates that MM1 exhibits an excess of 6.9 Jy, while MM2-4 are consistent with being unchanged. We conclude that MM1 has flared by a factor of 3.9 at 1.3 mm during the seven-year interval between the observations. In order to obtain a post-outburst image to compare with the pre-outburst SMA image with the best resolution (0.87 mm), we obtained ALMA DDT observations in this band in August 2016. The morphology of this image matches well with the 1.3 mm ALMA image observed one year earlier. Performing the same analysis on our 2016 ALMA and 2008 SMA data at 0.87 mm (**Fig. 1f-j**) yields an increase in the flux density of MM1 from 6.65 to 33.3 Jy. Similarly, the SMA could have recovered 84% (27.8 Jy) of the MM1 emission, yielding a comparable increase factor of 4.2, and confirming dust emission as the nature of the excess.

By fortunate coincidence, NGC6334I is one of several targets in a long-term maser monitoring program at the Hartebeesthoek Radio Observatory (HartRAO) using the 26m telescope. Strong flaring in 10 of 15 maser transitions from three species (H_2O, CH_3OH, and OH) toward NGC6334I began in early 2015 (MacLeod, G. et al., in preparation). In **Fig. 2** we show light curves for the 22 GHz H_2O and 6.7 GHz Class II CH_3OH maser lines, each for the component at -7.2 km s^{-1}, corresponding to the mean LSR velocity of the thermal molecular gas (Zernickel et al. 2012; Beuther et al. 2005). Both masers had increased by a factor of 10 by mid-May 2015 and the H_2O maser ultimately increased by a factor of 40 compared to our 2011 May VLA data (Brogan et al. 2016), an increase reminiscent of past flares in Orion-KL (Omodaka et al. 1999). While MM2 and MM3 were known to contain 6.7 GHz masers (Brogan et al. 2016), MM1 has never been detected in this line, nor in the 12.2 GHz Class II maser line, in three decades of interferometry dating back to the original VLBI observations (Norris et al. 1988). However, our recent VLA DDT observations show strong 6.7 GHz maser emission now coming from several locations across MM1

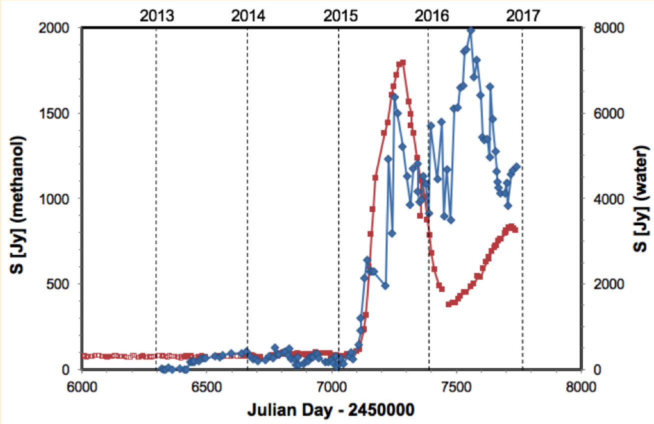

Figure 2: Light curves of total intensity from 6.7 GHz methanol (red squares) and 22.2 GHz water (blue diamonds) maser components associated with NGC 6334I, observed with the 26m HartRAO single dish. The same LSR velocity component, –7.2 km s^{-1}, is chosen for each maser species. The water maser measurements began on 2013 Jan 26.

(Hunter et al., in preparation), consistent with the increase in far infrared pumping radiation due to the outburst.

To estimate the increase in luminosity implied by the continuum flaring of MM1, we measured the change in 0.87 mm brightness temperature from 33 to 96 K (averaged over the region of excess emission). This factor of 2.9±0.3 increase provides a good proxy for the change in dust temperature, which scales as the ¼ power of the central luminosity in radiative transfer models of dust envelopes surrounding outbursting protostars (Johnstone et al. 2013); thus, we compute a luminosity increase factor of 70±20. The primary mechanism that could account for such a large outburst is a rapid increase in the accretion rate due either to disk fragmentation (Dunham & Vorobyov 2012) or an encounter with a neighboring protostar (Pfalzner et al. 2008) or gas clump (Meyer et al. 2017). While there are several massive protostars with candidate disks (Forgan et al. 2016), the first evidence for a disk-mediated accretion burst from a high-mass YSO was recently reported using infrared observations toward S255IR NIRS3 (Caratti o Garatti et al. 2017). It is similarly massive but less deeply-embedded than NGC6334I MM1. While its luminosity increase factor (~5.5) is lower than MM1, its initial luminosity is significantly larger. Nevertheless, the two events are quantitatively similar in terms of the rapid onset, sustained duration (>1 yr), and total energy, which points toward a common origin. For more details, please refer to Hunter, T. R. et al., 2017, ApJL, 837, 29. Further investigation of the physical nature of the accretion structures responsible for the outburst in MM1 is underway, including followup VLA imaging of the cm continuum and water masers, as well as a higher resolution (100 au) ALMA Cycle 4 long baseline project.

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CYGNUS X-3: ITS LITTLE FRIEND'S COUNTERPART, THE DISTANCE TO CYGNUS X-3 AND OUTFLOWS/JETS

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Cygnus X-3 is an unusual microquasar in which a compact object orbits a Wolf-Rayet companion with a 4.8-hour period (van Kerkwijk et al. 1992). It is a strong radio source routinely producing radio flare from 1-20 Jy (Waltman et al. 1995). Its radio emission shows correlations with both the soft and hard X-ray emission detected from this source (Szostek et al. 2008, McCollough, et al. 1999).

Chandra observations, made in 2000, found extended X-ray emission that is believed associated with Cygnus X-3 (Heindl et al. 2003). This feature was examined in data from a 2006 *Chandra* observation, which was longer, during a brighter X-ray state (McCollough, Smith, & Valencic 2013). It was shown from this and other *Chandra* observations of Cygnus X-3 that this feature was ~16 arc seconds away from Cygnus X-3 and extended (3.6 x 5.5 arc seconds) (see **Figure 1**). Surprisingly this feature showed the same 4.8-hour modulation seen Cygnus X-3 except it was shifted in phase by 0.56. In addition when Cygnus X-3 changed brightness between different *Chandra* observations over a 7-year period the feature (referred to as the "Little Friend") also showed the same level of increase or decrease in brightness. If this feature is at the same distance as Cygnus X-3 (taken to be 9 kpc with an uncertainty of 6.7-13 kpc (Predehl et al. 2000)) it would be 2.2 light years away from Cygnus X-3.

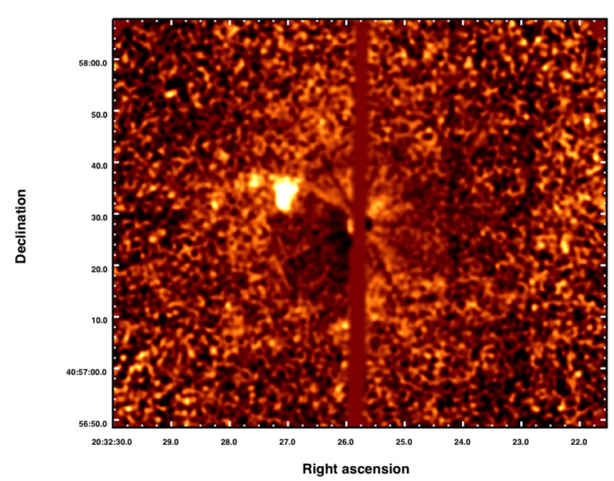

Figure 1: This is a smoothed X-ray (1-8 keV) image of the Little Friend with Cygnus X-3's Point Spread Function Removed and the instrumental readout streak mask out. One can clearly see the Little Friend.

An examination of the *Chandra* and radio data could not explain this feature in terms of the relativistic jets or the expected stellar winds associated with Cygnus X-3 (Heindl et al. 2003, McCollough, Smith, & Valencic 2013). The best explanation was what was being observed is X-ray scattering from dust in an interstellar cloud (McCollough, Smith & Valencic 2013). An analysis of the spectrum of the Little Friend and its scattered flux as compared to Cygnus X-3 give a column density of $5\text{x}10^{22}$ cm^{-2}. If one assumes that the time delay, seen in the X-ray, is due to a path difference between the Little Friend and Cygnus X-3 we can tell were the cloud lies relative to Cygnus X-3. Assuming a distance of 9 kpc to Cygnus X-3 it was found that the size of the cloud was between 0.1-0.2 pc. This would mean the density of the cloud would be ~10^5 cm^{-3} and would have a mass of between 2-24 $M_\odot$. The size, density, and mass are all consistent with a Bok Globule.

In order to confirm that the Little Friend is a Bok Globule SMA observations at 230 GHz were made to search for CO (2-1) emission from the cloud. Observations were made in early September 2015 and clearly detected ^{12}CO (2-1) and ^{13}CO (2-1) emission from the Little Friend at a velocity of -47.5 km s^{-1} (see **Figure 2**). No continuum emission at 1.3 mm, from the dust, was detected from the Little Friend. This non-detection gives a 3σ upper limit

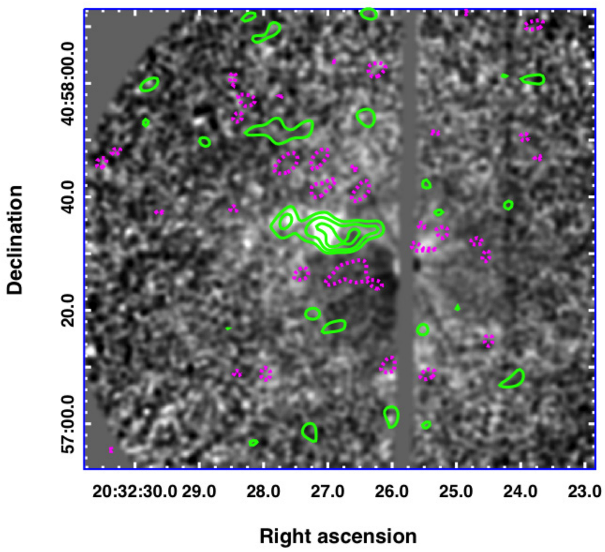

Figure 2: This is X-ray emission seen in Fig. 1, for the SMA field with contours ([-2,2,3,4] x 40 mJy/beam) of ^{13}CO (2-1) at -47.5 km s^{-1} overlaid (green positive values and dotted magenta for negative). This shows the clear association of the CO emission with the Little Friend.

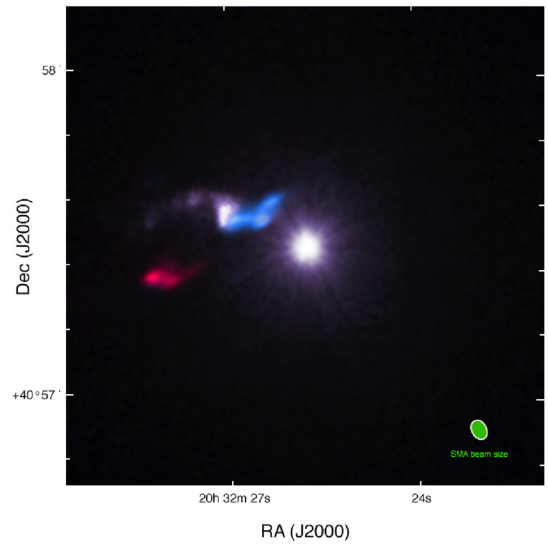

Figure 3: This is a composite image created from the X-ray (1-8 keV) Chandra data (purple/white) and CO emission obtained from the SMA showing the outflow/jet from the Little Friend. In the X-ray you can see Cygnus X-3 and the Little Friend. The blue is ^{12}CO (2-1) emission with negative velocities (0 to -2 km s^{-1}) relative to the strongest ^{13}CO (2-1), which we believe represents the rest velocity of the globule. The red is ^{12}CO (2-1) emission from positive velocities (1 km s^{-1}) that we believe are associated with the outflow/jet..

of 4.2 $M_\odot$ for the mass of the Little Friend and puts it at the low end of the mass range estimated from the X-ray data. From the velocity we can estimate the distance to the Little Friend using a parallax-based distance estimator tool (Reid et al. 2016). We find that the Little Friend is at a distance 6.08 ±0.64 kpc, which places it in the middle of the Perseus arm at a location where the local branch joins it (Xu et al. 2013) and where one would expect star formation. Now that we have a distance to the Little Friend we can use the X-ray scattering relationship to Cygnus X-3 to determine the distance to Cygnus X-3 (McCollough, Smith, & Valencic 2013). We find that Cygnus X-3 is located at a distance of 7.41±1.13 kpc. This is the most accurate distance to Cygnus X-3 to date.

A somewhat unexpected result of these observations is that there is clear evidence of outflow/jets from the Little Friend in both ^{12}CO (2-1) and ^{13}CO (2-1) (see **Figure 3**). Such outflows/jets are known to occur in molecular clouds (Arce et al. 2007, Frank et al. 2014). This clearly indicates that a protostar has formed in the Little Friend and that a molecular outflow has started to occur.

In this study (McCollough, Corrales, & Dunham 2016) we have found the molecular counterpart to the first, and to date the most distance, Bok Globule to have been seen in the X-ray. Also as a result of this work we have determined the most accurate distance to Cygnus X-3 to date (~15% uncertainty). Finally, in CO emission we see outflows/jets from the Little Friend that give a clear indication that a protostar has indeed formed and is creating an outflow.

To better understand this system we have had two more SMA observations taken that are being reduced. One in the extend array configuration for better resolution and the other in the sub-compact array to give us a better measure of the total CO.

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THE GALACTIC CENTER MOLECULAR CLOUD SURVEY: A FIRST VIEW WITH THE SMA

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The Central Molecular Zone (CMZ) — the inner ~200 pc of our Galaxy — is a star–forming environment with extreme physical properties. About 3–10% of the total molecular gas and star formation of the Milky Way1 reside at $|l| \leq 3°$. CMZ molecular clouds have unusually high mean H_2 densities ~10^4 cm^{-3} and column densities ~10^{23} cm^{-2}, and they are subject to an average gas pressure from hot gas of order $10^{6 \text{ to } 7}$ K cm^{-3}. The gas has unusually high temperatures ~50 K, and it is pervaded by a strong magnetic field of a few 10^3 μG that also penetrates the CMZ clouds. Unusually wide lines $\gtrsim$10 km s^{-1} on spatial scales $\gtrsim$1 pc and widespread emission from various molecules (like SiO) indicate that the gas is subject to violent gas motions and shocks (see Kauffmann et al. 2016a for references on all these aspects). The clouds appear to lie on a well–organized common orbit (e.g., Molinari et al. 2011 and Kruijssen et al. 2015) along which clouds might also systematically evolve (Longmore et al. 2013).

Previous research into CMZ star formation has established the *bulk* properties of molecular clouds comprehensively. What was missing to date was a detailed understanding of the resolved characteristics of clouds on spatial scales $\lesssim$1 pc on which individual stars form. For this purpose we launched the Galactic Center Molecular Cloud Survey (GCMS), the first systematic survey that resolves all major CMZ clouds with SMA, ALMA, and CARMA. Here we summarize first results from this work (Kauffmann et al. 2016a,b).

The GCMS focuses on tracers of the dense gas in molecular clouds, as illustrated in **Figure 3**. In the work published now we focus on the emission from dust and the N^2H^+ (3–2) transition near 280 GHz frequency. These observations primarily probe the gas on spatial scales $\lesssim$1 pc that set the initial conditions for the formation of individual stars. Additional single–dish observations from APEX permit to also explore larger spatial scales, including the gas kinematics of entire clouds. These data reveal a number of startling trends. Some of these cloud characteristics were known from previous observations; the GCMS data now establish these findings as general characteristics of CMZ molecular clouds.

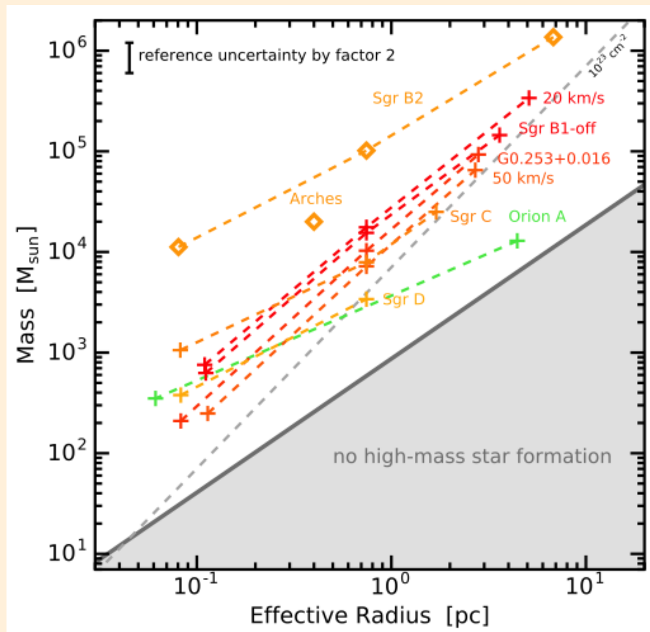

Figure 1: Mass–size data for molecular clouds. Shades of red and orange indicate data for Galactic Center molecular clouds studied by the GCMS. The green line gives reference data for the Orion A molecular cloud.

First, the observations provide a new look at one of the most fascinating aspects of CMZ molecular clouds: the suppression of star formation in the dense gas. Molecular clouds near sun form about one star per 1 Myr for every 5 $M_\odot$ of gas at high densities 10^4 cm^{-3}. But in the CMZ this rate is lower by a factor $\gtrsim$10. Research into the suppression of Galactic Center star formation motivates studies of the CMZ like the GCMS.

Second, the GCMS data now show for the first time that most CMZ molecular clouds have unusually shallow density gradients,

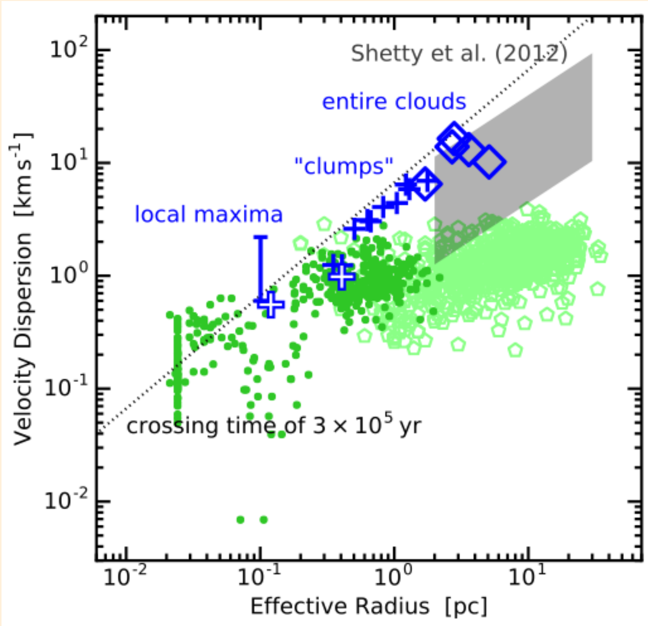

Figure 2: Linewidth–size data for molecular clouds. Green symbols indicate data for Galactic Disk molecular clouds from Kauffmann et al. (2013). Blue markers present measurements for the Galactic Center obtained by the GCMS. Grey shading outlines results previously obtained by Shetty et al. (2012).

compared to clouds in the disk of the Milky Way. This manifests in unusually steep mass–size relations for these clouds, as shown in **Figure 1**. This diagram combines data on the mass and size of the most massive structure in a cloud identified on spatial scales ~0.1 pc, ~1 pc, and ~5 pc. In the case of the Orion A cloud, for example, we see that about 3% of the cloud's total mass (i.e., 350 $M_\odot$ out of 13,000 $M_\odot$) are contained in the cloud's most massive core of ~0.1 pc size. By contrast, the most massive core in the 20 km s^{-1} cloud (**Figure 3**) only contains 0.2% of the cloud's total mass (i.e., 750 $M_\odot$ out of 339,000 $M_\odot$). An intuitive understanding of these observations can be obtained making the — highly simplistic — assumption that the clouds are spheres with power–law density profiles. Then the data indicate density laws $n(r)\propto r^{-1.3}$, much shallower than what thought to be typical for molecular clouds. It seems likely that this relative absence of higher–density gas contributes to the aforementioned suppression of CMZ star formation.

Third, the linewidth–size relation prevailing in CMZ molecular clouds appears to be much steeper than what is found elsewhere in the Milky Way. This is illustrated in **Figure 2**. Specifically, on spatial scales $\gtrsim$1 pc we find that CMZ molecular clouds have line widths much above those observed for molecular clouds in the Milky Way's disk. This is consistent with previous knowledge about CMZ clouds. But on smaller spatial scales we can now confidently establish a new trend: considering scales ~0.1 pc, the line widths found in CMZ molecular clouds are not different from what is found in molecular clouds residing in the Galactic Disk. We can confirm the well–known trend that clouds in the Galactic Center are unusually "turbulent" — but this only holds for large spatial scales. Rather quiescent conditions are found on small scales.

Combined with the information on the cloud density structure this means that the overall dynamics governing star formation on spatial scales ~0.1 pc are — in terms of kinematics and den-

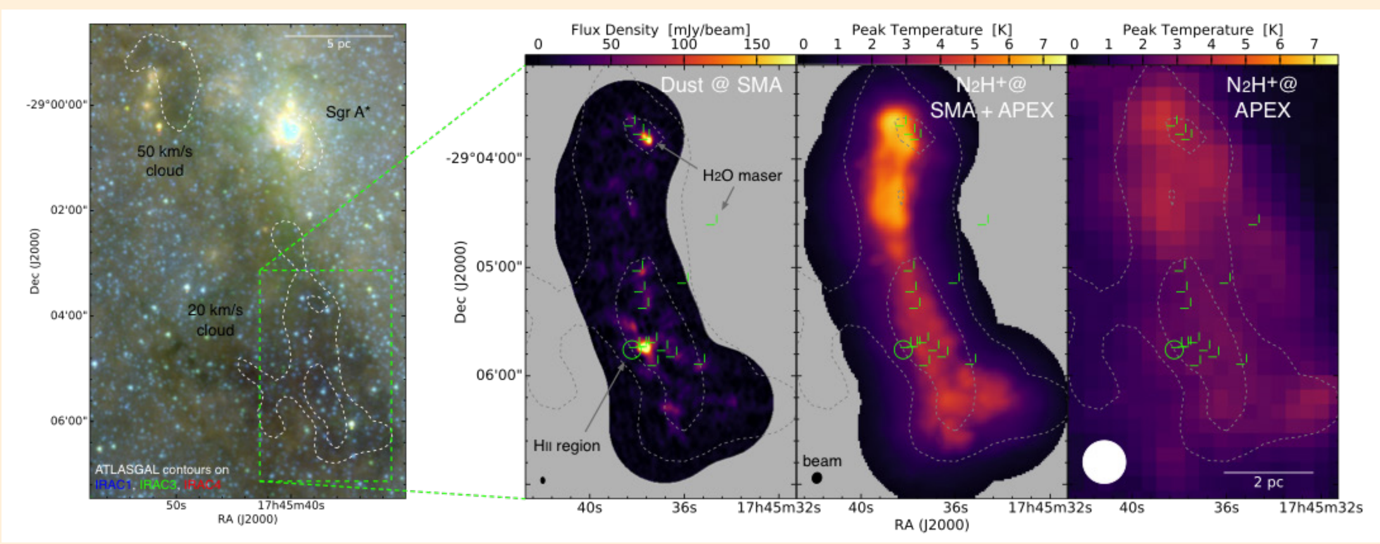

Figure 3: Example observations of the 20 km s^{-1} cloud. The left panel shows Spitzer IRAC data. The right panel presents dust continuum emission near 280 GHz as observed by the SMA, combined APEX and SMA observations of the N_2H^+ (3–2) transition, and APEX–only observations of the N_2H^+ (3–2) transition covering a larger area. All panels are overlaid with contours of single–dish dust continuum emission at 870 µm wavelength from APEX at arbitrary chosen levels. The green circle indicates the location of an HII region, while green crosses give the location of water masers discovered by Lu et al. (2015).

sities — not different for clouds inside and outside of the CMZ. This is a critical insight if we wish to understand why star formation in the dense gas of the CMZ is suppressed.

Fourth, we find that the clouds do not follow any clear evolutionary pattern. Molinari et al. (2011) established that CMZ molecular clouds appear to be organized in a ring–like structure orbiting Sgr A*. Longmore et al. (2013) suggested that clouds come relatively close to Sgr A* on their somewhat elongated orbits, and proposed that cloud collapse is triggered during these close encounters. This would result in an organized evolutionary sequence between clouds: clouds should start out as "starless" objects, they would then turn into objects with moderate star formation, and they would eventually end up in spectacular starbursts, similar to what is seen in the Sgr B2 complex. The GCMS now provides comprehensive data to test this picture. The observations show that the star formation rate per unit dense gas does not increase significantly along the orbit. Similarly, the cloud density structure does not evolve in an obvious way along the trajectory of clouds. In summary we find no indications for an evolutionary sequence along CMZ cloud orbits. It seems more likely that the star formation activity in a given cloud remains low over long time scales and is not tied to specific sections of a cloud's orbit.

The GCMS has laid the foundations for further CMZ projects with the SMA, such as the CMZoom large–scale program, which will be described in one of the forthcoming issues of this periodical. The GCMS itself continues to focus on the exploration of the major CMZ molecular clouds. It has already collected further data sets on further telescopes, including ~30 h of observing time on ALMA, that will be analyzed in the next year.

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THE *HERSCHEL*-ATLAS: A SAMPLE OF 500 μM-SELECTED STRONGLY LENSED GALAXIES OVER 600 DEG²

Negrello M. (Cardiff University, UK) and the *Herschel*-ATLAS team

Strong gravitational lensing events are the most striking examples of how gravity affects the fabric of space and, consequently, the path of photons reaching us from distant sources in the Universe. They occur when a massive object lies very close to the line-of-sight to a distant galaxy: the foreground mass acts as a *lens* by re-directing photons from the background galaxy towards the Earth, thus increasing its apparent luminosity. The lens also induces the formation of multiple images of the background galaxy, which are stretched over large areas, thus providing a magnified view of the distant source. These two combined effects make strong lensing events powerful astrophysical tools, used to carry out a detailed investigation of the physical and morphological properties of high redshift sources and to probe the distribution of dark matter in the Universe.

Unfortunately, such events are rare, as they rely on an almost perfect alignment between the observer and two sources at different redshifts. Therefore wide area surveys and efficient methods to pick up strongly lensed galaxies are needed to find them in a significant number.

For decades, optical and radio observations have provided large data sets to be exploited for this kind of search, together with the sub-arcsecond spatial resolution needed to recognise the typical features of strong lensing, i.e. multiple images, arcs and rings (e.g. Treu 2010). However, thanks to the wide area images provided by the *Herschel* space observatory (Pilbratt et al. 2010) we can now carry out a systematic search for lensed galaxies also at sub-millimeter wavelengths.

The *Herschel* Astrophysical Terahertz Large Area Survey (*H*-ATLAS; Eales et al. 2010) is the widest area extragalactic survey undertaken with *Herschel*, covering more than 600 square degrees of the sky and providing a sample of more than a hundred of thousands of high redshift (z > 1) dusty star-forming galaxies (DSFGs) for statistical studies. One of its scientific goals is the systematic search of strong lensing events. Unfortunately, both

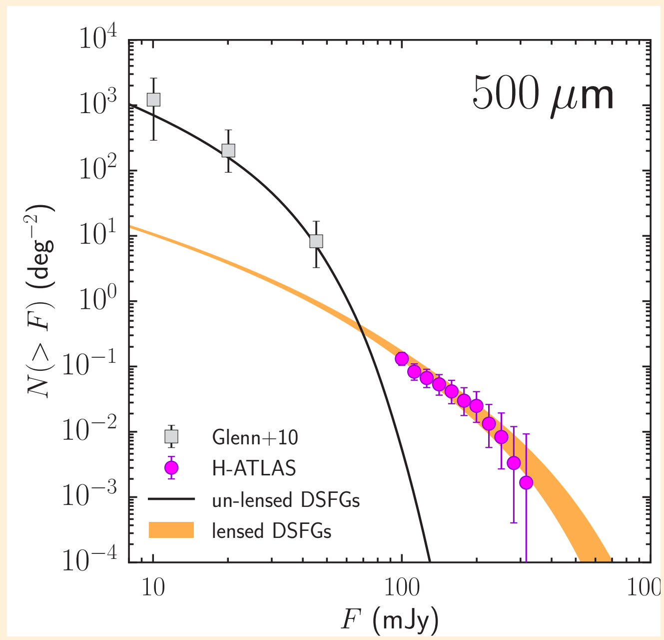

Figure 1: Integral number counts of z>1 dusty star-forming galaxies (DSFGs) at 500 μm, illustrating the simple method to identify gravitationally lensed galaxies in wide area sub-millimeter surveys. The number density of high redshift dusty galaxies (solid black curve) drops off very rapidly at 100 mJy; therefore, almost exclusively those galaxies whose flux density has been boosted by gravitational lensing can be seen above that threshold. The orange shaded area is the expected number density of lensed DSFGs for maximum magnification in the range 10 to 15. The integral counts of candidate lensed galaxies identified in the H-ATLAS is shown by the purple dots. So far at least 20 sources in the sample have been confirmed to be lensed galaxies [see Negrello et al. (2017) for details]

lensed and un-lensed DSFGs appear as featureless "blobs" in the *Herschel* images because of the limited spatial resolution of the telescope. In fact, in a strong lensing event the typical separation between multiple images is of the order to one to few arcseconds, a scale more than 10 times smaller than the ones probed by *Herschel*. So, how to single out lensed sources from the un-lensed ones in the *Herschel* data?

This is made possible by the (predicted) steep number counts of high redshift DSFGs (e.g. Blain 1996, Negrello et al. 2007), such that almost exclusively those galaxies whose flux density has been boosted by an event of lensing can be observed above a certain flux density, namely ~ 100 mJy at 500 µm (**Figure 1**). Therefore, a simple cut in flux density is enough to identify lensed galaxies in wide area sub-millimeter surveys. Any contaminant, in the form of either very nearby galaxies or radio bright blazars - which also appear as sub-millimeter bright sources -, is easily identified and removed by means of shallow optical and radio imaging data.

In a proof of concept paper (Negrello et al. 2010) we reported the discovery of 5 gravitationally lensed galaxies over the first 16 deg^2 of the *H*-ATLAS using a simple cut in flux density at 500µm. The Submillimeter Array (SMA) has played a crucial role in confirming the lensing nature of these sources (e.g. Bussmann et al. 2013; Negrello et al. 2014). In fact, the lensed galaxy is relatively faint at optical to near-infrared wavelengths, because of dust obscuration and redshift, and is, in general, over come by the emission from the foreground object that acts as a lens, typically a massive elliptical galaxy. Therefore, high-resolution follow-up observations at sub-millimeter and millimeter wavelengths are needed to reveal the multiple images of the background source (**Figure 2**).

We have now extended the search for strong lensing events over the entire *H*-ATLAS area (Negrello et al. 2017), using the same simple selection technique. We have identified 80 candidate lensed galaxies with flux density $F_{500\mu m}$>100mJy over ~600 deg^2. At least 20 of them, which includes 80% of those with $F_{500\mu m}$>150mJy, are confirmed to be lensing systems based on available optical/near-infrared to sub-millimeter/millimeter spectroscopic and high-resolution imaging data (**Figure 3** provides some examples; see also Bussmann et al. 2012, 2013), while follow-up observations are still ongoing to confirm the nature of the others.

The lensed galaxies in our sample have redshifts ranging from 1 to 4.2, with a median value z = 2.5. Their infrared luminosity (integrated over the rest-frame wavelength range 8 to 1000 µm) exceeds $10^{13}\,L_{\odot}$, and even $10^{14}\,L_{\odot}$ in few cases, thus making these sources some of the apparently brightest star-forming galaxies in the Universe. However, these estimates are not corrected for the effect of lensing: with an expected (or measured, where possible) magnifications of ~5-15, the galaxies in our sample are more likely to have infrared luminosities in the range 10^{12}-$10^{13}\,L_{\odot}$.

The boost in brightness due to gravitational lensing is what makes these sources so valuable in probing the properties and physical conditions of the interstellar medium in high redshift star-forming galaxies. In fact, spectroscopic follow-up observations of such bright targets are less time demanding, allowing the swift detection of emission lines from e.g. carbon monoxide (Lupu et al. 2012; Harris et al. 2012), water vapor (Omont et al. 2011, 2012; Yang et al. 2016) and dense molecular gas tracers HCN, HCO^+ and HNC (Oteo et al. 2017).

Thanks to the increase in spatial resolution offered by gravitational lensing, our sample is also ideal for studying the morphological and dynamical properties of z ~ 2 DSFGs down to sub-kpc scales, as recently demonstrated by the analysis of the high-resolution observations of HATLAJ090311.6+003907 (aka SDP.81) obtained with the Atacama Large Millimeter Array (e.g. Dye et al. 2015 and references therein) as part of its long baseline campaign (ALMA partnership 2015). In this respect, it is important to note that, for sub-millimeter selected lensed galaxies, the contamination of the lens – typically a passively evolving elliptical galaxy – to the sub-millimeter emission of the background galaxy is negligible (**Figure 2**). Therefore, the modeling of the lensed morphol-

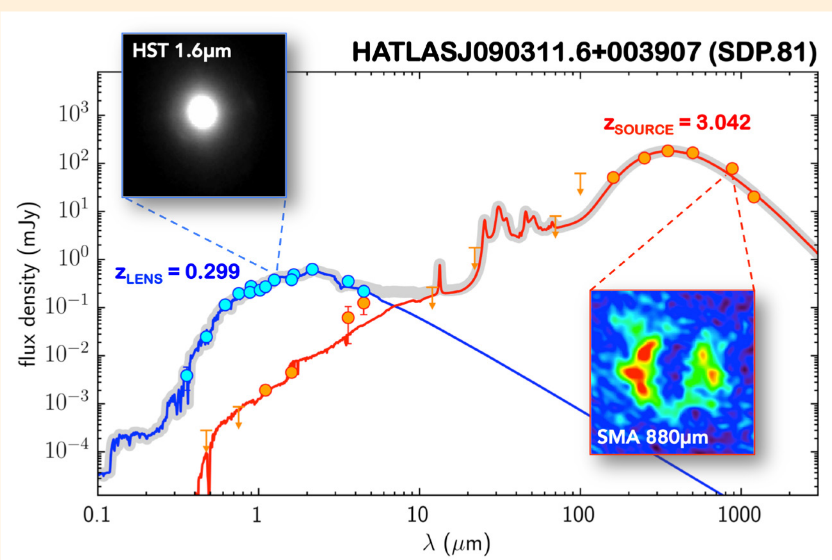

Figure 2: Spectral energy distribution of the lens (blue) and of the background galaxy (red) for the gravitational lensing system HATLASJ090311.6+003907 (aka SDP.81) [see Negrello et al. 2014 for details]. It illustrates how observations at different wavelengths probe different components of the lensing system: the foreground galaxy (i.e. the lens) in the optical to near-IR (as probed by e.g. the *Hubble* Space Telescope, in the upper left inset) and the dust-obscured background galaxy in the far-infrared to millimeter (as probed by e.g. the SMA, in the lower right inset).

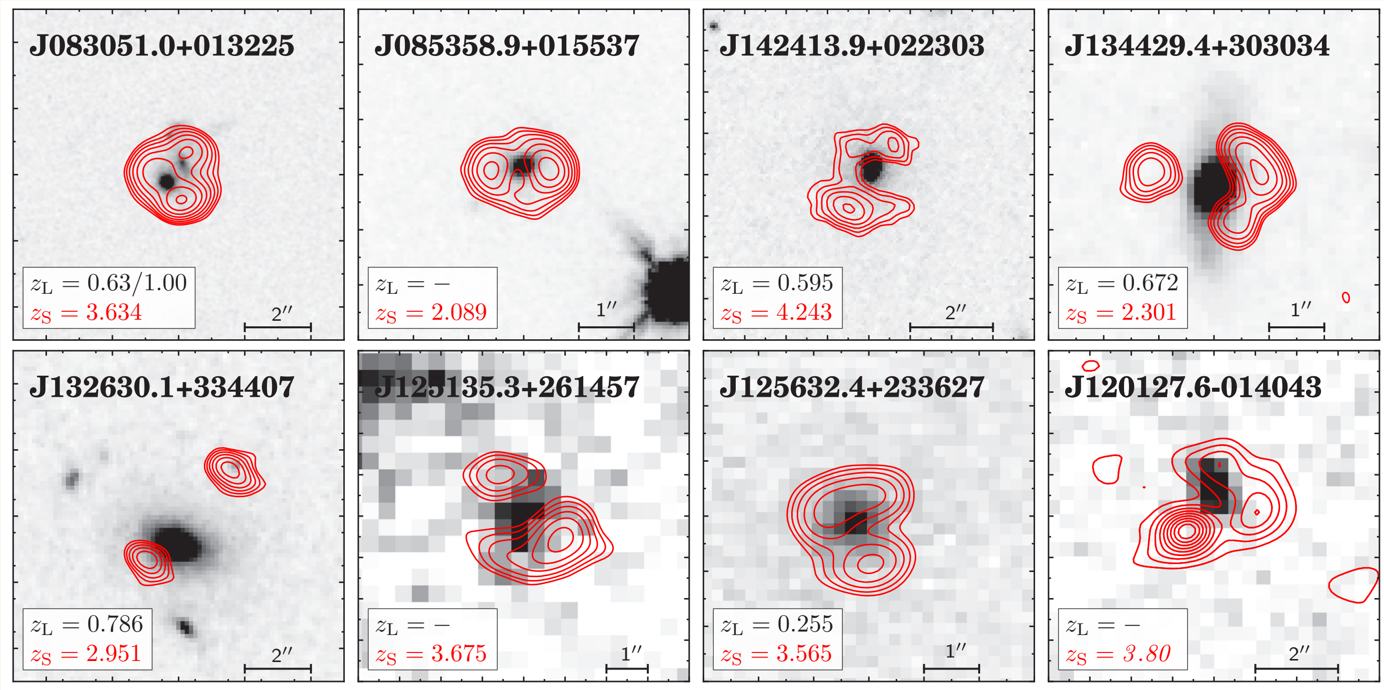

Figure 3: Examples of galaxy-scale lensing systems in the H-ATLAS confirmed via follow-up observations with the Submillimeter Array (SMA). With its sub-arcsecond spatial resolution the SMA has played - and is still playing - a key role in probing the nature of the sub-millimeter brightest extragalactic sources, by resolving the characteristic features of gravitational lensing, i.e. multiple images and arcs (red contours superimposed to near-infrared images; the redshifts of the lens and of the source are shown in the insets). HATLASJ120127.6-014043, in the bottom right panel, is the latest object in the Negrello et al. 2017 sample that we confirmed to be lensed with the SMA data obtained over the last semester (Enia et al. in prep.)

ogy does not suffer from uncertainties on the lens subtraction, as usually happens in optically selected lensing systems.

It is also worth noticing that our selection technique exploits the properties of the background galaxy alone, i.e. its sub-millimeter flux density, and therefore it is not biased against the redshift and the mass of the lens. In fact, we already have a few confirmed lenses with redshifts $z_L >\sim 1$. This opens up the possibility of probing the mass distribution and the abundance of dark matter substructures in galaxies out to significantly higher redshifts than done so far (e.g. Dye et al. 2014, Hezaveh et al. 2016).

We have modeled the number counts of our candidate lensed galaxies using the physical model of Cai et al. (2013) for the formation and evolution of z > 1 DSFGs, which accurately fits a broad variety of data: multi-frequency and multi-epoch luminosity functions of galaxies, redshift distributions, and number counts. The dark matter halo mass function provided by N-body simulations (e.g. Sheth & Tormen 1999) is adopted to describe the number density of the lenses. The cross-section for strong gravitational lensing is computed assuming a Navarro-Frank-White plus a de Vaucouleurs profile for the mass distribution, which results in the isothermal power law profile usually inferred from the modeling of individual lensing systems (e.g. Dye et al. 2014 and references therein). One major uncertainty in predicting the abundance of lensed galaxies is related to the intrinsic size of the background sources, which affects the maximum magnification they can reach and, therefore, the shape of the counts at the brightest flux densities. Magnifications up to 10-30 are predicted for sources in the redshift range z=1-4 and with sizes of 1 to 10 kpc (Perrotta et al. 2002; Lapi et al. 2012).

We find that the predicted number counts of lensed DSFGs are in excellent agreement with the observations for maximum amplifications in the range 10 to 15 (**Figure 1**). These values are consistent with those derived from the modeling of individual lensed galaxies performed on SMA imaging data (Bussmann et al. 2013).

We are currently increasing the size of our sample by selecting candidate lensed galaxies down to 80 mJy at 500 µm (Bakx et al., MNRAS submitted), but we expect up to ~1000 lensed galaxies to be identified in the *H*-ATLAS in the future by pushing our selection to even fainter flux densities and exploiting photometric redshifts information together with available near-infrared imaging data (Gonzalez-Nuevo et al. 2012).

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SCIENCE WITH THE WIDEBAND SMA: A STRATEGY FOR THE DECADE OF 2017-2027

David Wilner (CfA)

Numerous astronomers from the SMA community have contributed to a whitepaper that describes examples of the scientific impact of the planned wideband SMA development. The executive summary of this whitepaper is reproduced below. More detail can be found in **SMA Technical Memo No. 165** (January 27, 2017).

The Submillimeter Array (SMA) comprises eight movable 6-meter diameter antennas sited on Maunakea, Hawaii, designed for high spatial and spectral resolution observations at submillimeter wavelengths. Pioneering observations with the SMA have provided new insights into a wide variety of astrophysical phenomena, including the formation and evolution of galaxies, stars and planets, and the nature of the supermassive black hole at the center of the Milky Way. Following careful deliberation, the SMA project is embarking on an ambitious, staged, strategic upgrade that will increase its instantaneous bandwidth and dramatically improve its observational sensitivity and speed. The unique capabilities of this ultra-wideband SMA – the "wSMA" – promise to spark a new era of forefront discoveries.

In brief, the wSMA upgrade will provide a core receiver set providing dual-polarization observing bands covering the 345 GHz and 230 GHz atmospheric windows, each with 32 GHz of spectral coverage. Together with upgrades of the signal transport system and digital correlator, this brings a factor of 16 increase in instantaneous bandwidth from the original SMA capability. For continuum observations, speed increases linearly with bandwidth to a given level of sensitivity, enabling more observations to the same depth in the same amount of time. Or, for a given amount of time, the sensitivity increases as the square root of bandwidth, enabling deeper observations. For line observations, spectral coverage increases linearly with bandwidth, enabling observations of many lines simultaneously, all at high spectral resolution. In effect, every wSMA observation of an astronomical source is an imaging spectral line survey, and an enormous amount of information can be extracted from such data in conjunction with physical, chemical and dynamical models. This whitepaper elaborates on illustrative examples in key scientific areas, including the evolutionary state of protostellar sources, the chemistry of evolved star envelopes, the constituents of planetary atmospheres, starburst galaxies in the local Universe and at high redshifts, and even low-mass galaxies at high redshifts through the technique of intensity mapping. The wSMA speeds up observations to allow systematic, comparative studies of large numbers of spectral surveys for the first time. The wSMA also will be ideally suited for the study of sources in the time domain. Illustrative examples include the variability of the accretion flow onto the SgrA* black hole, capturing emission from gamma ray bursts from massive star deaths in the early universe and the mergers of compact objects that produce gravitational waves, and resolved spectroscopy of the pristine material that escapes from comets as they traverse the inner Solar System.

The wSMA will be complementary to the larger international Atacama Large Millimeter/ sub-millimeter Array (ALMA) in Chile, which followed the SMA into submillimeter interferometry in 2011. The immense time pressure on ALMA from its many constituencies only creates an increasing need for the wSMA, notably for the large class of observations that do not require ALMA's full sensitivity or angular resolution, as well as for unique submillimeter access to the northern sky. The wSMA will play a leading role in select science areas in the ALMA era, including those requiring long-term programs to build large samples, or rapid response based on flexible scheduling, as well as for high risk seed studies specifically designed for subsequent ALMA follow-up. In addition, the wSMA will be a critical station for submillimeter VLBI observations of supermassive black holes in the global Event Horizon Telescope, which will be bolstered by the inclusion of ALMA in 2017. Finally, the wSMA design explicitly incorporates open space for additional instrumentation to pursue new and compelling science goals and technical innovations, continuing its role as a pathfinder for submillimeter astronomy.

SMA WAS A KEY STATION IN THE 2017 EVENT HORIZON TELESCOPE OBSERVING CAMPAIGN

André Young, Ken Young, and Jonathan Weintroub

The Event Horizon Telescope (EHT) observed with a larger array than ever before for five full nights in April 2017. In addition to SMA, the array consisted of eight participating telescopes at six geographic locations. The other seven were: South Pole, APEX, ALMA, LMT, JCMT, SMT and the IRAM 30m. The observed nights were the 5th, 6th, 7th, 10th and 11th April.

Good luck favored a well prepared EHT team. The weather for these five nights was typically very good across the array, and technical problems were mostly absent and manageable when they did occur. The primary EHT targets were M87 and SgrA*, as usual, though a broader set of AGN science targets including 3c279, OJ287, NGC1052 and CenA were observed based on an open call for proposals though ALMA. All the projected allocated observations were completed.

SMA participated with SWARM running at full sample rate and bandwidth, sampling at 4576 mega samples per second to produce 410 TB of phased array data. That is in addition to 350 TB of data recorded for an SMA single dish and the JCMT, to bring the total for Mauna Kea to almost 0.75 petabytes. As in previous years, the SMA phased array data needs to be preprocessed before being ready for correlation with data from other VLBI stations. This interpolation and inversion to time series is currently in-process using the Adaptive Phased-array Heterogeneous Interpolating Downsampler for SWARM (APHIDS).

The data were split into high and low bands, each of 2GHz bandwidth with two bands per polarization. The VLBI correlators at MIT Haystack Observatory and Max Planck Institute for Radioastronomy in Bonn are processing the low and high bands respectively for all stations. All disk modules were shipped and have been received at the processing centers except, of course, for those that remain at the South Pole. When the South Pole station opens to air traffic again in the Austral Spring, the data modules from April can, at last, be shipped to the correlator. Given the shipping time via McMurdo Sound and New Zealand is a couple of weeks, we reasonably expect processing of this data to commence only in November 2017, about seven months after the data were acquired. All matching data at other stations needs to be retained until this time of course.

APHIDS is run off-line on a GPU compute server. Over the next couple of months, summer intern Mark Peryer will be working on developing an FPGA-based real-time preprocessor, which will enable recording VLBI correlation-ready data directly at the summit during an observation. The target hardware platform for this application is the SKARAB, built around the Xilinx Virtex 7 FPGA, the next generation relative to the Virtex 6 used in SWARM.

At this stage, initial VLBI detections have been found to all stations (with the exception of the South Pole) for AGN calibrators, and work continues on refining station parameters in preparation for further processing. This is very encouraging news as it verifies setup and operation at all the sites processed so far. In particular, all three stations recorded at the Maunakea station, being SWARM, the SMA single dish, and the JCMT, have been verified.

A diverse multi-wavelength network observed SgrA*, M87, and other AGN along with the EHT. As the EHT data processing progresses, we will keep in close touch with our multi-wavelength colleagues for joint analysis. All signs point to the 2017 EHT data set being very rich scientifically. We are entering an exciting era both for the EHT and the SMA's participation.

Figure 1: Working 16.5 hour shifts the teams at various global sites began to amuse themselves by recreating "album cover band photos" and sharing them on Slack. The Maunakea team snapped this one entitled "The Grateful Fringes". From the left Geoff Bower, Remo Tilanus, André Young, and Jonathan Weintroub. Photo by Jonathan Weintroub using a self-timer.

Figure 2: The excellent weather and full moon combined to yield this photo of five SMA dishes observing 3C279 taken just before midnight on 10 April HST. Photo by Jonathan Weintroub.

ERIC KETO RETIRES

After a long and distinguished career – 5 years at Harvard, 10 years at the University of California, and 22 years at SAO – Eric Keto has retired. He will become a Research Associate with the Institute for Theory and Computation at Harvard University starting this fall.

Dr. Eric Keto has been an Astrophysicist at the Smithsonian Astrophysical Observatory; Project Scientist for the Submillimeter Array and Associate Senior Member for the Institute for Theory and Computation.

During his years at SAO, Dr. Keto was part of the team that designed and constructed the Submillimeter Array telescope. In particular, he designed the configuration of the Submillimeter Array's antennas for optimal Fourier transform imaging. This novel design, based on the Reuleaux triangle, was later used as the basis for the dithering pattern used by the Spitzer Space Telescope for optimal calibration. He also designed and developed the Submillimeter Array's data recording and calibration software.

His research interests include hydrodynamics and radiative transfer in the interstellar medium, combining observational and theoretical studies to better understand the evolution of molecular clouds in our own and in distant galaxies.

Dr. Keto is a frequent observer at radio-frequency telescopes and also the author of the MOLLIE program. MOLLIE is a publicly available computer code for numerical simulation of observations of molecular lines. A unique feature of this program is the modeling of hyperfine lines in the molecular spectra. The program allows researchers to test theoretical models of three-dimensional gas flows in the interstellar medium against observations.

Previously, Dr. Keto was a Physicist at the University of California's Lawrence Livermore National Laboratory. There he helped with the commissioning of the Berkeley mid-infrared array camera that was built at the Space Sciences Laboratory at UC Berkeley.

Dr. Keto earned his BA at Princeton and his PhD at Harvard. Along the way, he has been a visiting scholar at the Max Planck Institute for Astronomy in Heidelberg and a Visiting Professor at the University of Leeds.

The Eric R. Keto prize, awarded annually to a graduating student at Harvard University for the best PhD thesis in theoretical astrophysics, is named in his honor in acknowledgment of his generous donation.

Thank you, Eric, for all your contributions to the SMA. Happy Retirement!

Along with Institute for Theory and Computation party, Eric celebrates with Radio & Geoastronomy Division.
From the left Giovanni Fazio, Jim Moran, Jenny Keto (Eric's wife), Bob Wilson and Eric Keto.

STAFF CHANGES IN HILO

John Cheng, ASIAA IT specialist, is leaving at the end of July to pursue an educational opportunity. John has worked for over a decade supporting the SMA and the Hilo offices. We thank John for his efforts and wish him success in the future.

Ramona Sekona, Administrative Support Assistant, joined SAO at the end of June, reporting to Simon Radford. Before the SMA, Ramona worked at the Pohakuloa Training Area in the saddle between Maunakea and Maunaloa.

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 high percentage of our past Fellows have gone on to permanent faculty and research staff positions located around the world.

The SMA welcomes our newest Fellows:

Luca Matrà received his Ph.D. from the Institute of Astronomy, University of Cambridge (UK) in winter 2017, with the thesis 'Exocometary gas in debris disks' (Advisors: Mark Wyatt, Bill Dent, and Olja Panić). Luca has interests in exocomets, their compositions, debris disks and the origin of planetary systems, non-LTE radiative transfer modeling of gas line emission in circumstellar disks, and comparison and modeling of optical/IR observations with mm/submm observations.

María J. Jiménez-Donaire is finishing her Ph.D. work at the University of Heidelberg, with the thesis 'The EMIR Nearby Galaxy Dense Gas Survey' (Advisor: Frank Bigiel). María's research is in observational extragalactic astronomy focusing on star formation processes and the interstellar medium (ISM) properties of nearby galaxies. She has a particular interest in the use of multi-wavelength data sets to understand how the physical (and increasingly also the chemical) properties of the ISM regulate star formation across galaxies.

Dr. Matrà has already started his fellowship as of June 1, while (soon to be) Dr. Jiménez-Donaire will take up her fellowship in early 2018. They join continuing SMA Fellows Shaye Storm, Junko Ueda, Tomasz (Tomek) Kaminski, and Garrett (Karto) Keating.

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

- **Luca Ricci** moved in late 2016 to Rice University, continuing his work in the observational study of protoplanetary disks
- **Cara Battersby,** previously an SMA Fellow and current NSF Astronomy and Astrophysics Fellow in residence here at the CfA, will begin working as Assistant Professor of Astronomy at the University of Connecticut in fall 2017

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 2018 SMA Fellowship opportunities will be in early October 2017.

Mark A. Gurwell
Chair, SMA Fellowship Selection Committee

POSTDOCTORAL OPPORTUNITIES WITH THE SMA

Applications for the 2018 Submillimeter Array (SMA) Postdoctoral Fellowship program will be due in fall 2017. We anticipate offering one or more SMA Postdoctoral Fellowships starting Summer/Fall 2018.

The 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. The SMA recently commissioned a next generation correlator which vastly increases total bandwidth (to 8 GHz/sideband per polarization) while retaining high spectral resolution (140 kHz) across the entire processed spectral range, providing significantly enhanced science capability.

These positions are aimed chiefly at research, both observational and theoretical, in submillimeter astronomy. Successful candidates will participate in remote and on-site 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 early October 2017. 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 November 16, 2017 - May 15, 2018 (2017B semester). The deadline for submitting proposals is **Wednesday, September 06, 2017**.

The SMA has recently completed significant upgrades in observational capability, with more underway. Currently, the SMA observes simultaneously with two orthogonally polarized receivers, one in the 230 GHz or 345 GHz band and the other in the 240 GHz or 400 GHz band (with full polarimetric observations available using the 230+240 or 345+400 band combinations). The SWARM correlator processes 8 GHz bandwidth for each receiver in each sideband, for a total of 32 GHz, at a uniform 140 kHz resolution. This 32 GHz frequency coverage can be continuous where the tuning ranges overlap for the two orthogonally polarized receivers. In short, the SMA now provides flexible, wide band frequency coverage that delivers high continuum sensitivity and excellent spectral line capabilities. A full track offers continuum sensitivity of 200 or 500 micro-Jy (1 sigma) at 230 or 345 GHz in good weather conditions (precipitable water vapor 2.5mm and 1.0mm, respectively). The corresponding line sensitivities at 1 km/s resolution are 30 and 70 mJy. The small antennas allow access to low spatial frequencies in the sub-compact configuration and the finest angular resolution at 345 GHz in the very extended configuration is ~ 0.25". Thus, in some ways, the characteristics of the SMA may be both similar and complementary to those of the stand-alone Atacama Compact Array (ACA) component of ALMA. For more information about SMA capabilities, visit the SMA Observer Center website and explore the set of SMA proposing tools. Current and archived SMA Newsletters available online provide a sampling of the wide variety of science possible with the SMA.

The SMA Observer Center website (http://sma1.sma.hawaii.edu/proposing.html) is expected to open for proposal submission on August 15, 2017.

The SMA also invites proposals for large-scale observing projects dedicated to answering major astrophysical questions having significant scientific impact. More details can be found at: http://sma1.sma.hawaii.edu/call_largescale.html

T. K. Sridharan
Chair, SMA Time Allocation Committee

PROPOSAL STATISTICS 2017A (16 MAY 2017 – 15 NOV 2017)

The SMA received a total of 76 proposals (SAO 52) requesting observing time in the 2017A 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	16
submm/hi-z galaxies	15
local galaxies, starbursts, AGN	7
evolved stars, AGB, PPN	4
protoplanetary, transition, debris disks	4
other	3
Galactic center	2
GRB, SN, high energy	2
UH	2
solar system	1

TRACK ALLOCATIONS BY WEATHER REQUIREMENT (ALL PARTNERS):

PWV[1]	SAO	ASIAA	UH[2]
< 4.0mm	17A + 42B	1A + 8B	12
< 2.5mm	30A + 25B	8A + 0B	0
< 1.0mm	0A + 0B	0A + 2B	0
Total	**47A + 67B**	**9A + 10B**	**12**

(1) Precipitable water vapor required for the observations.

(2) UH does not list As and Bs.

TOP-RANKED SAO AND ASIAA PROPOSALS – 2017A 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
High angular resolution imaging of the proto-planetary nebula CRL 618

Po-Sheng Huang, ASIAA
Shaping A Widely Expanded Bipolar Pre-Planetary Nebula by A Precessing Jet

Xiaohu Li, Academia Sinica Institute of Astronomy & Astrophysics (ASIAA)
"Parent" or "Daughter"? The challenging problem raised by single-dish observations of molecular CN and HCN toward S-type AGB stars

GALACTIC CENTER

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
Constraining 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

Qizhou Zhang, CfA
How to make massive protostellar cluster?

Shih-Ping Lai, National Tsing Hua University, Taiwan
Pilot mosaic polarization observations towards W51 and Orion BN/KL

Susanne Wampfler, Center for Space and Habitability, University of Bern
Constraining the spatial distribution of H3O+ in a star-forming region

T.K. Sridharan, CfA
Misaligned Magnetic Field in IRAS 20126+4104

LOCAL GALAXIES, STARBURSTS, AGN

Geoffrey Bower, ASIAA
Variability Timescale of Low Luminosity AGN

Junko Ueda, Smithsonian Astrophysical Observatory
Star Formation Efficiency and Molecular Gas Distribution in LIRGs at the early-stage of merger

LOW/INTERMEDIATE MASS STAR FORMATION, CORES

Hyunju Yoo, Chugnam National University
EC 53, a Test-Bed for Episodic Accretion

Lars Kristensen, Center for Star & Planet Formation, Niels Bohr Institute, Copenhagen University
Protostellar Interferometric Line Survey (PILS): Cygnus X

Nacho Añez, Institut de Ciències de l'Espai (ICE, IEEC-CSIC)
What is controlling the fragmentation process?

Raghvendra Sahai, Jet Propulsion Laboratory
Stellar Embryos in Free-floating EGGs: A New Astrophysical Laboratory for Triggered Star Formation

Ramprasad Rao, ASIAA SMA
Does Polarization from Scattering Contaminate Magnetic Field Observations in Star Forming Regions?

Siyi Feng, Dr.
Sulfur and organic chemistry in the shocked region L1157-B1 & B2

OTHER

Tomasz Kaminski, CfA, SMA fellow
A search for molecular emission in historical novae: towards a test of explosive nucleosynthesis

PROTOPLANETARY, TRANSITION, DEBRIS DISKS

Amy Steele, University of Maryland at College Park
Circumstellar Material after the Main Sequence

SOLAR SYSTEM

Mark Gurwell, Harvard-Smithsonian Center for Astrophysics
Imaging the Troposphere-Stratosphere Boundary on Neptune with SWARM

SUBMM/HI-Z GALAXIES

Fabrizio Arrigoni Battaia, ESO (Garching)
Enormous Lyman-Alpha Nebulae as Signposts of Nascent Protoclusters

Jesus Rivera, Rutgers, the State University of New Jersey
SMA mapping of ACT dusty star-forming galaxies

Stephen Serjeant, The Open University
Monsters at the edge of the map: finding extreme starbursting quasars at the highest redshifts

ALL SAO PROPOSALS – 2016B SEMESTER

The following is the listing of all SAO proposals observed in the 2016B semester (16 Nov 2016 – 15 May 2017).

Elizabeth Artur de la Villarmois, Niels Bohr Institute
Unlocking the protostellar carbon chemistry with SWARM

Geoffrey Bower, ASIAA
Molecular Gas in the Host Galaxy of FRB 121102

Scott Chapman, Dalhousie University
Tomography of the IGM: resolving the SMGs near QSOs uncovered by the SCUBA2-WEB large program

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

Lennox Cowie, University of Hawaii
The Growth of the Most Massive Galaxies and Supermassive Black Holes

Sheperd Doeleman, CfA
Imaging Black Hole Shadows: Event Horizon Telescope observations of Sgr A and M87*

Judit Fogasy, Chalmers University of Technology
Tracing the star formation in the environment of high-z quasars

Soren Frimann, Niels Bohr Institute
Tracing chemical effects of episodic accretion towards low-mass protostars

Naomi Hirano, ASIAA
Searching for the FHSC candidate source in the Planck could clump G204NE

Garrett "Karto" Keating, CfA
Charting the Cosmic History of Molecular Gas with Intensity Mapping

Francisca Kemper, ASIAA
The mysterious object KIC 8462852: Is there a large dust reservoir around this Sun-like star?

Lars Kristensen, Copenhagen University
Ice to gas: determining the desorption efficiency of methanol

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

Tie Liu, Korea Astronomy and Space Science Institute
On the properties of Class 0/I Young Stellar Objects in the Lambda Orionis molecular complex

Xing Lu, National Astronomical Observatory of Japan
Understanding Formation of Low-mass Stars in Clusters with Observations of Hubs

Mattia Negrello, Cardiff University
SMA imaging of Herschel-ATLAS candidate lensed galaxies

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

Oteo Gómez, University of Edinburgh
The molecular gas of low-z submm galaxies

Oteo Gómez, University of Edinburgh
Towards a sample of z~7 dusty starbursts

Oteo Gómez, University of Edinburgh
The most luminous starbursts in the early Universe

Hsi-an Pan, ASIAA
The Impact of Minor Merger on Galaxy Evolution and Massive Star Formation Environment: an indispensable piece of cosmic galaxy evolution framework

Nimesh Patel, CfA
AY191 - Water Emission in VY CMa

Magnus Persson, Chalmers University of Technology
Testing water deuteration processes: high- vs. low-mass protostars

Charlie Qi, CfA
Catching an Outbursting Comet

Charlie Qi, CfA
Outbursting Comet C/2017 E4 (Lovejoy)

Keping Qiu, Nanjing University
Mapping the molecular bullets in HH80-81: the first proper motion experiment for EHV molecular gas in a high-mass protostar

Peter Scicluna, ASIAA
Grain growth in Herschel selected post-AGB stars with discs

Kazimierz Sliwa, MPIfR
A Cloud-Scale Map of CO J=2-1-to-J=1-0 Line Ratio in M51

Shaye Storm, CfA
Star Clusters in Formation: Probing their Young Stellar Systems

Yoshiki Toba, ASIAA
Search for most infrared luminous galaxy in the Universe

Yuji Urata, NCU/ASIAA
New Insights in Short GRBs

Dyas Utomo, University of California, Berkeley
What controls the gas consumption time in galaxy centers?

Nienke van der Marel, University of Hawaii
Flaring and Accretion in the Pre-Main Sequence Binary System DQ Tau

Nienke van der Marel, University of Hawaii
Millimeter imaging survey of new transition disk candidates

Nienke van der Marel, University of Hawaii
Planet Formation in the Earliest Stages of Star Formation

Susanne Wampfler, University of Bern
Constraining the spatial distribution of H3O+ in a star-forming region

Wei-Hao Wang, ASIAA
The Faint High-Redshift Tail of the Submillimeter Galaxy Population

Jacob White, University of British Columbia
Measuring the Emission from Sirius A's Stellar Atmosphere

Jonathan Williams, University of Hawaii
SMA imaging of FU Orionis objects

David Wilner, CfA
The 61 Vir Planetary System Debris DIsk

Min Yun, University of Massachusetts
Probing Dense Gas Powering SF/AGN Activities in High-z SMGs using Lensing

Jorge Zavala, INAOE
A Dusty Star-forming Galaxy at z=6: Revealing An Unreachable Population of Galaxies

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

Qizhou Zhang, CfA
AY191 - Is Frosty Leo an evolved star?

RECENT PUBLICATIONS

Title: A Submillimeter Perspective on the Goods Fields. II. The High Radio Power Population in the Goods-N
Authors: Barger, A. J.; Cowie, L. L.; Owen, F. N.; Hsu, L.-Y.; Wang, W.-H.
Publication: *The Astrophysical Journal, Volume 835, Issue 1, article id. 95, 9 pp. (2017).*
Publication Date: 01/2017
Abstract: http://adsabs.harvard.edu/abs/2017ApJ...835...95B

Title: A concordant scenario to explain FU Orionis from deep centimeter and millimeter interferometric observations
Authors: Liu, Hauyu Baobab; Vorobyov, Eduard I.; Dong, Ruobing; Dunham, Michael M.; Takami, Michihiro; Galván-Madrid, Roberto; Hashimoto, Jun; Kóspál,Ágnes; Henning, Thomas; Tamura, Motohide; Rodríguez, Luis F.; Hirano, Naomi; Hasegawa, Yasuhiro; Fukagawa, Misato; Carrasco-Gonzalez, Carlos; Tazzari, Marco
Publication: *Astronomy & Astrophysics, Volume 602, id.A19, 10 pp.*
Publication Date: 01/2017
Abstract: http://adsabs.harvard.edu/abs/2017arXiv170106531L

Title: High dense gas fraction in intensely star-forming dusty galaxies at high redshift
Authors: Oteo, I.; Zhang, Z-Y.; Yang, C.; Ivison, R. J.; Omont, A.; Bremer, M.; Bussmann, S.; Cooray, A.; Cox, P.; Dannerbauer, H.; Dunne, L.; Eales, S.; Furlanetto, C.; Gavazzi, R.; Nayyeri, H.; Negrello, M.; Neri, R.; Riechers, D.; Van der Werf, P.
Publication: *eprint arXiv:1701.05901*
Publication Date: 01/2017
Abstract: http://adsabs.harvard.edu/abs/2017arXiv170105901O

Title: Herschel and Hubble study of a lensed massive dusty starbursting galaxy at z ~ 3
Authors: Nayyeri, H.; Cooray, A.; Jullo, E.; Riechers, D. A.; Leung, T. K. D.; Frayer, D. T.; Gurwell, M. A.; Harris, A. I.; Ivison, R. J.; Negrello, M.; Oteo, I.; Amber, S.; Baker, A. J.; Calanog, J.; Casey, C. M.; Dannerbauer, H.; De Zotti, G.; Eales, S.; Fu, H.; Michałowski, M. J.; Timmons, N.; Wardlow, J. L.
Publication: *eprint arXiv:1701.01121*
Publication Date: 01/2017
Abstract: http://adsabs.harvard.edu/abs/2017arXiv170101121N

Title: Signs of Early-stage Disk Growth Revealed with ALMA
Authors: Yen, Hsi-Wei; Koch, Patrick M.; Takakuwa, Shigehisa; Krasnopolsky, Ruben; Ohashi, Nagayoshi; Aso, Yusuke
Publication: *The Astrophysical Journal, Volume 834, Issue 2, article id. 178, 23 pp. (2017).*
Publication Date: 01/2017
Abstract: http://adsabs.harvard.edu/abs/2017ApJ...834..178Y

Title: Molecular Outflows: Explosive versus Protostellar
Authors: Zapata, Luis A.; Schmid-Burgk, Johannes; Rodríguez, Luis F.; Palau, Aina; Loinard, Laurent
Publication: *The Astrophysical Journal, Volume 836, Issue 1, article id. 133, 10 pp. (2017).*
Publication Date: 02/2017
Abstract: http://adsabs.harvard.edu/abs/2017ApJ...836..133Z

Title: Growth of a Massive Young Stellar Object Fed by a Gas Flow from a Companion Gas Clump
Authors: Chen, Xi; Ren, Zhiyuan; Zhang, Qizhou; Shen, Zhiqiang; Qiu, Keping
Publication: *The Astrophysical Journal, Volume 835, Issue 2, article id. 227, 10 pp. (2017).*
Publication Date: 02/2017
Abstract: http://adsabs.harvard.edu/abs/2017ApJ...835..227C

Title: The Herschel-ATLAS: a sample of 500 μm-selected lensed galaxies over 600 deg2
Authors: Negrello, M.; Amber, S.; Amvrosiadis, A.; Cai, Z.-Y.; Lapi, A.; Gonzalez-Nuevo, J.; De Zotti, G.; Furlanetto, C.; Maddox, S. J.; Allen, M.; Bakx, T.; Bussmann, R. S.; Cooray, A.; Covone, G.; Danese, L.; Dannerbauer, H.; Fu, H.; Greenslade, J.; Gurwell, M.; Hopwood, R.; Koopmans, L. V. E.; Napolitano, N.; Nayyeri, H.; Omont, A.; Petrillo, C. E.; Riechers, D. A.; Serjeant, S.; Tortora, C.; Valiante, E.; Verdoes Kleijn, G.; Vernardos, G.; Wardlow, J. L.; Baes, M.; Baker, A. J.; Bourne, N.; Clements, D.; Crawford, S. M.; Dye, S.; Dunne, L.; Eales, S.; Ivison, R. J.; Marchetti, L.; Michałowski, M. J.; Smith, M. W. L.; Vaccari, M.; van der Werf, P.
Publication: *Monthly Notices of the Royal Astronomical Society, Volume 465, Issue 3, p.3558-3580*
Publication Date: 03/2017
Abstract: http://adsabs.harvard.edu/abs/2017MNRAS.465.3558N

Title: A Submillimeter Perspective on the GOODS Fields (SUPER GOODS). I. An Ultradeep SCUBA-2 Survey of the GOODS-N
Authors: Cowie, L. L.; Barger, A. J.; Hsu, L.-Y.; Chen, Chian-Chou; Owen, F. N.; Wang, W.-H.
Publication: *The Astrophysical Journal, Volume 837, Issue 2, article id. 139, 30 pp. (2017).*
Publication Date: 03/2017
Abstract: http://adsabs.harvard.edu/abs/2017arXiv170203002C

Title: Angular Momentum in Disk Wind Revealed in the Young Star MWC 349A
Authors: Zhang, Qizhou; Claus, Brian; Watson, Linda; Moran, James
Publication: *The Astrophysical Journal, Volume 837, Issue 1, article id. 53, 8 pp. (2017).*
Publication Date: 03/2017
Abstract: http://adsabs.harvard.edu/abs/2017arXiv170202975Z

Title: An Extraordinary Outburst in the Massive Protostellar System NGC6334I-MM1: Quadrupling of the Millimeter Continuum
Authors: Hunter, T. R.; Brogan, C. L.; MacLeod, G.; Cyganowski, C. J.; Chandler, C. J.; Chibueze, J. O.; Friesen, R.; Indebetouw, R.; Thesner, C.; Young, K. H.
Publication: *The Astrophysical Journal Letters, Volume 837, Issue 2, article id. L29, 6 pp. (2017).*
Publication Date: 03/2017
Abstract: http://adsabs.harvard.edu/abs/2017arXiv170108637H

Title: The effect of ram pressure on the molecular gas of galaxies: three case studies in the Virgo cluster
Authors: Lee, Bumhyun; Chung, Aeree; Tonnesen, Stephanie; Kenney, Jeffrey D. P.; Wong, O. Ivy; Vollmer, B.; Petitpas, Glen R.; Crowl, Hugh H.; van Gorkom, Jacqueline
Publication: *Monthly Notices of the Royal Astronomical Society, Volume 466, Issue 2, p.1382-1398*
Publication Date: 04/2017
Abstract: http://adsabs.harvard.edu/abs/2017MNRAS.466.1382L

Title: Submillimeter Array 12CO (2-1) Imaging of the NGC 6946 Giant Molecular Clouds
Authors: Wu, Ya-Lin; Sakamoto, Kazushi; Pan, Hsi-An
Publication: *The Astrophysical Journal, Volume 839, Issue 1, article id. 6, 10 pp. (2017).*
Publication Date: 04/2017
Abstract: http://adsabs.harvard.edu/abs/2017ApJ...839....6W

Title: The physical and chemical structure of Sagittarius B2. II. Continuum millimeter emission of SgrB2(M) and SgrB2(N) with ALMA
Authors: Sanchez-Monge, A.; Schilke, P.; Schmiedeke, A.; Ginsburg, A.; Cesaroni, R.; Lis, D. C.; Qin, S.-L.; Mueller, H. S. P.; Bergin, E.; Comito, C.; Moeller, Th.
Publication: *eprint arXiv:1704.01805*
Publication Date: 04/2017
Abstract: http://adsabs.harvard.edu/abs/2017arXiv170401805S

Title: The Molecular Gas Environment in the 20 km s-1 Cloud in the Central Molecular Zone
Authors: Lu, Xing; Zhang, Qizhou; Kauffmann, Jens; Pillai, Thushara; Longmore, Steven N.; Kruijssen, J. M. Diederik; Battersby, Cara; Liu, Hauyu Baobab; Ginsburg, Adam; Mills, Elisabeth A. C.; Zhang, Zhi-Yu; Gu, Qiusheng
Publication: *The Astrophysical Journal, Volume 839, Issue 1, article id. 1, 18 pp. (2017).*
Publication Date: 04/2017
Abstract: http://adsabs.harvard.edu/abs/2017ApJ...839....1L

Title: Magnetic Fields in the Massive Dense Cores of the DR21 Filament: Weakly Magnetized Cores in a Strongly Magnetized Filament
Authors: Ching, Tao-Chung; Lai, Shih-Ping; Zhang, Qizhou; Girart, Josep M.; Qiu, Keping; Liu, Hauyu B.
Publication: *The Astrophysical Journal, Volume 838, Issue 2, article id. 121, 18 pp. (2017).*
Publication Date: 04/2017
Abstract: http://adsabs.harvard.edu/abs/2017ApJ...838..121C

Title: Luminous Infrared Galaxies with the Submillimeter Array. V. Molecular Gas in Intermediate to Late-stage Mergers
Authors: Sliwa, Kazimierz; Wilson, Christine D.; Matsushita, Satoki; Peck, Alison B.; Petitpas, Glen R.; Saito, Toshiki; Yun, Min
Publication: *The Astrophysical Journal, Volume 840, Issue 1, article id. 8, 15 pp. (2017).*
Publication Date: 05/2017
Abstract: http://adsabs.harvard.edu/abs/2017ApJ...840....8S

Title: Millimeter Observations of the disk around GW Ori
Authors: Fang, M.; Sicilia-Aguilar, A.; Wilner, D.; Wang, Y.; Roccatagliata, V.; Fedele, D.; Wang, J. Z.
Publication: *eprint arXiv:1705.01917*
Publication Date: 05/2017
Abstract: http://adsabs.harvard.edu/abs/2017arXiv170501917F

Title: A Massive Prestellar Clump Hosting No High-mass Cores
Authors: Sanhueza, Patricio; Jackson, James M.; Zhang, Qizhou; Guzman, Andres E.; Lu, Xing; Stephens, Ian W.; Wang, Ke; Tatematsu, Ken'ichi
Publication: *The Astrophysical Journal, Volume 841, Issue 2, article id. 97, 14 pp. (2017).*
Publication Date: 06/2017
Abstract: http://adsabs.harvard.edu/abs/2017arXiv170408264S

Title: Magnetized converging flows towards the hot core in the intermediate/high-mass star-forming region NGC 6334 V
Authors: Juárez, Carmen; Girart, Josep M.; Zamora-Avilés, Manuel; Tang, Ya-Wen; Koch, Patrick M.; Liu, Hauyu Baobab; Palau, Aina; Ballesteros-Paredes, Javier; Zhang, Qizhou; Qiu, Keping
Publication: *eprint arXiv:1706.03534*
Publication Date: 06/2017
Abstract: http://adsabs.harvard.edu/abs/2017arXiv170603534J

Title: Observational evidence that positive and negative AGN feedback depends on galaxy mass and jet power
Authors: Kalfountzou, E.; Stevens, J. A.; Jarvis, M. J.; Hardcastle, M. J.; Wilner, D.; Elvis, M.; Page, M. J.; Trichas, M.; Smith, D. J. B.
Publication: *eprint arXiv:1706.02334*
Publication Date: 06/2017
Abstract: http://adsabs.harvard.edu/abs/2017arXiv170602334K

Title: Simultaneous low- and high-mass star formation in a massive protocluster: ALMA observations of G11.92-0.61
Authors: Cyganowski, C. J.; Brogan, C. L.; Hunter, T. R.; Smith, R.; Kruijssen, J. M. D.; Bonnell, I. A.; Zhang, Q.
Publication: *Monthly Notices of the Royal Astronomical Society, vol. 468, issue 3, pp. 3694-3708*
Publication Date: 07/2017
Abstract: http://adsabs.harvard.edu/abs/2017arXiv170102802C

Title: A study of the wiggle morphology of HH 211 through numerical simulations
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*
Publication Date: 08/2016
Abstract: http://adsabs.harvard.edu/abs/2016MNRAS.460.1829M

Title: Extreme jet ejections from the black hole X-ray binary V404 Cygni
Authors: Tetarenko, A. J.; Sivakoff, G. R.; Miller-Jones, J. C. A.; Rosolowsky, E. W.; Petitpas, G.; Gurwell, M.; Wouterloot, J.; Fender, R.; Heinz, S.; Maitra, D.; Markoff, S. B.; Migliari, S.; Rupen, M. P.; Rushton, A. P.; Russell, D. M.; Russell, T. D.; Sarazin, C. L.
Publication: *Monthly Notices of the Royal Astronomical Society, Volume 469, Issue 3, p.3141-3162*
Publication Date: 08/2017
Abstract: http://adsabs.harvard.edu/abs/2017arXiv170408726T

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

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