SMA Newsletter

Submillimeter Array Newsletter | Number 27 | January 2019

CONTENTS

SCIENCE HIGHLIGHTS:

TECHNICAL HIGHLIGHTS:

OTHER NEWS

FROM THE DIRECTOR

Dear SMA Newsletter readers,

After a month's delay due to the US government shutdown, during which many SMA staff were on furlough, I am now happy to release this Newsletter, with science articles on a wide range of topics that make good use of SMA instrument capabilities and flexibility in scheduling. The first of these, led by Anna Ho of Caltech, describes observations of a young, nearby, rapidly rising optical transient that became one of the most intensely observed cosmic explosions in history, and was monitored by the SMA over a 50-day period. The second article, with SMA observations led by Harvard University undergraduate Charles Law, focuses on the extended CO emission in the interacting galaxy NGC 3627. These observations made good use of the SMA's mosaicing capability, and combined SMA data with data from the IRAM 30 m telescope as well as archival data from observatories no longer in use. The third article: Multi-wavelength Light Curves of Two Remarkable SgrA* Flares, led by SAO scientist Giovanni Fazio, is a result of coordinated observing campaigns at many facilities, including the SMA. The fourth article, led by Sheng-Yuan Liu of ASIAA, again makes use of multi-epoch observations to try to understand the origin of a recent luminosity burst in S255IR. Together, these articles showcase the exciting science done by the SMA, as well as its broad user base.

Finally, please see the SMA call for proposals on page 17, and be mindful of the fact that, despite the shutdown, we have elected not to delay the deadline for proposal submission for semester 2019A, which covers the period May 16th – November 15th.

Ray Blundell

SMA OBSERVATIONS OF AT2018cow: A PROTOTYPE FOR MILLIMETER TIME-DOMAIN ASTRONOMY

Anna Y. Q. Ho (Caltech)

Recent discoveries by optical time-domain surveys challenge our understanding of how energy is deposited and transported in stellar explosions. Commonly-invoked mechanisms for depositing energy include radioactive decay (Colgate & McKee 1969) and shock heating (Grassberg 1971, Chevalier 1976). Together, these explain the locations of most optical transients in the parameter space of rise-time and luminosity. However, the faster cadence and wider areal coverage of modern surveys have unlocked new regions of parameter space — for example, the region of short rise-times and high peak luminosities (Drout et al. 2014; Arcavi et al. 2016; Tanaka et al. 2016; Whitesides et al. 2017; Pursiainen et al. 2018; Rest et al. 2018). To explain these "fast-luminous" transients, model parameters must be taken to extremes, or entirely new power sources must be considered; see Kasen (2017) for a review.

Most of the approximately 100 fast-luminous transients were found in archival searches at cosmological distances, so could not be studied in detail. As a result, the ATLAS survey's discovery on 16 June 2018 of the young, nearby, rapidly rising, and luminous optical transient AT2018cow (Smartt et al. 2018; Prentice et al. 2018) generated considerable excitement. Over the following few months, AT2018cow became one of the most intensely observed cosmic explosions in history (Rivera Sandoval et al 2018; Kuin et al. 2018; Perley et al. 2018; Margutti et al. 2018; Ho et al. 2018).

Our observations of AT2018cow using the SMA, recently published in the Astrophysical Journal (Ho et al. 2018), represent a milestone in millimeter time-domain astronomy. Although it has become common to follow up optical transient discoveries with centimeter-wave-

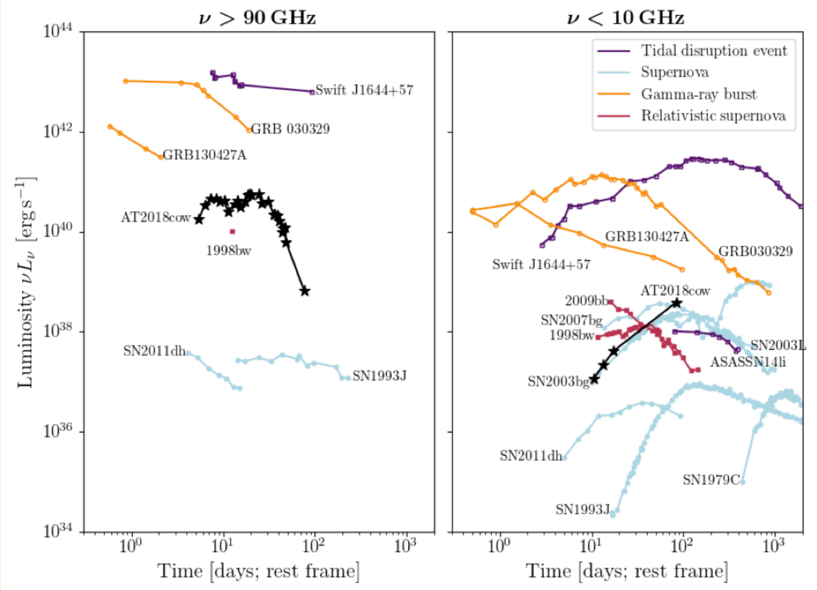


Figure 1: Millimeter- (left panel) and centimeter-wavelength (right panel) light curves for several classes of extragalactic transients. The millimeter transient sky remains poorly explored. A number of other explosions (SN2007bg, SN2003L, SN2009bb) have similar low-frequency light curves to AT2018cow, and would likely have been luminous millimeter transients at early times, had they been observed by millimeter observatories (promisingly, SN1998bw, a relative of SN2009bb, was observed by SCUBA and had a single detection).

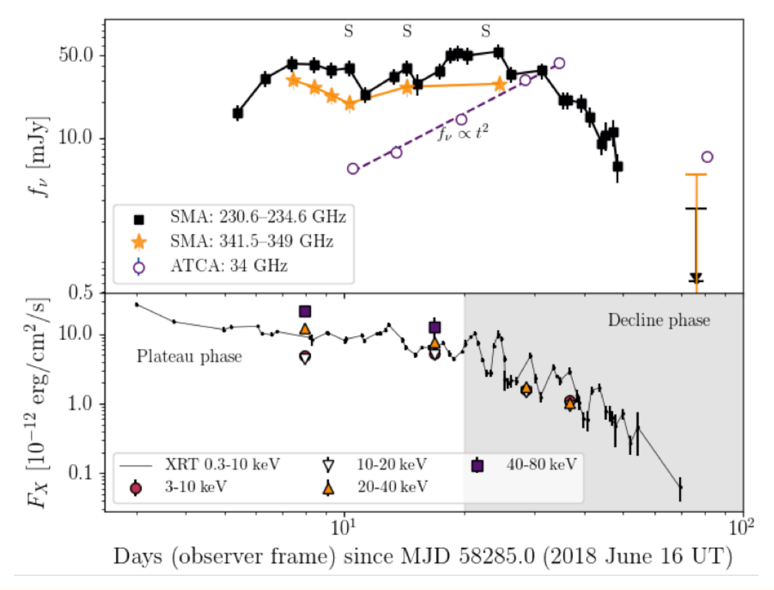


Figure 2: Millimeter (SMA), centimeter (ATCA), and X-ray (Swift/XRT and NuSTAR) light curves for AT2018cow. SMA observations of AT2018cow represent the first detection of a transient rising at millimeter wavelengths. By 50 days after the optical discovery, the interaction has diminished, shown by a rapid fall-off in millimeter emission. The smooth (t^2) rise at 34 GHz reflects the fact that emission is self-absorbed at these frequencies, meaning that the peak of the SED would be hidden to the low-frequency facilities (like the VLA) that are typically used to observe extragalactic transients.

length (low-frequency) facilities like the Very Large Array, successful follow-up at millimeter wavelengths (high frequencies) has been rare (see **Figure 1**). This is because after a few days, for most known classes of transients, the peak of the synchrotron spectrum lies at centimeter wavelengths.

We began observing AT2018cow with the SMA four days after the optical discovery, and the millimeter light curves are shown in the top panel of **Figure 2**. To our great surprise, the transient exhibited millimeter emission that was more luminous than any known supernova, rivaled only by a handful of relativistic jetted explosions (gamma-ray bursts and Swift J1644+57). Over the next few nights, the millimeter emission increased in brightness, representing the first time any cosmic explosion has been caught rising at high frequencies. The light curve reached a plateau of 50 mJy at 230 GHz which lasted from 8 days after the explosion to 30 days after. The millimeter emission then faded, marking a sudden decrease or end to interaction with the surrounding medium. Around this same time, there was an abrupt change to the X-ray light curve, shown in the bottom panel of **Figure 2**. The X-ray emission began to diminish, to exhibit significant temporal variability, and to soften (as reflected in the NuSTAR data). We refer to these two phases as the "plateau phase" and the "decline phase," and suggest that the transition (indicated by a shaded region in the bottom panel of **Figure 2**) represents the unveiling of the central engine of the explosion, likely an accreting black hole or a newborn magnetar.

In our paper, we show that this luminous millimeter emission is a consequence of two factors: the large energy released in the event, and the high density of the surrounding medium. Motivated by the bright SMA detection, we acquired broad-band ALMA observations at 22 days post-explosion. Constraining the peak of the SED enabled us to model the properties of the shockwave driven into the surrounding medium, assuming a population of electrons with a power-law number distribution in Lorentz factor (a typical assumption in modeling synchrotron spectra, and expected in well-tested

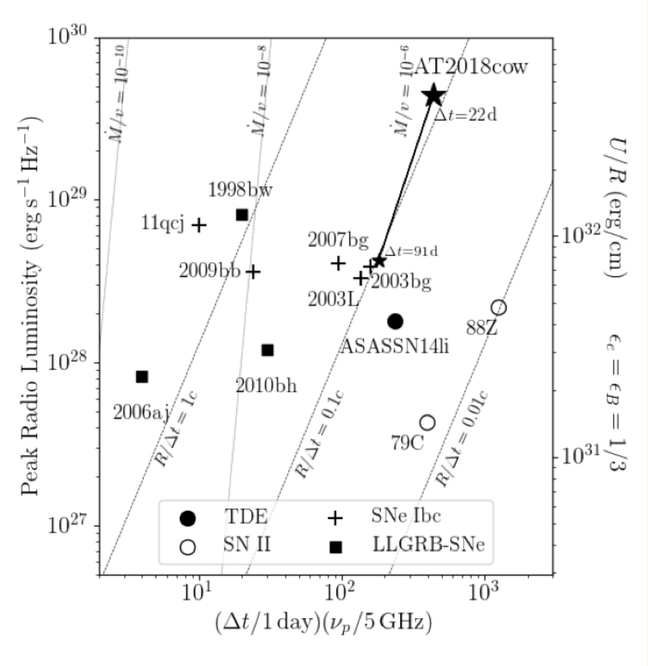


Figure 3: Peak time and frequency (x-axis) vs. peak radio luminosity (y-axis) inferred from the synchrotron self-absorption frequency and peak flux constrained by ALMA at Δt=22 days. The product of peak time and peak frequency roughly traces the mass-loss rate, shown (scaled by velocity) as nearly vertical lines. As shown on the right-hand axis, the peak radio luminosity reflects U/R, the amount of energy processed by the shock into pressure divided by the radius of the shockwave. AT2018cow is unusual in having such a luminous peak at high frequencies, and this reflects a large amount of energy propagating into a dense medium.

theories of acceleration of electrons in supernova shocks). Following the framework in Chevalier (1998), we infer a forward-shock radius of R ~ 7 x 10^{15} cm (and a corresponding mean velocity of 0.13*c*), a magnetic field strength B ~ 6 G, and a total energy in the shock of U > 4 x 10^{48} erg. From conservation of momentum, we infer an electron number density in the surrounding medium of 3 x 10^5 cm^{-3}. We show in **Figure 3** that the high radio luminosity is a consequence of the large energy swept up at this blastwave radius, and the high peak frequency is a consequence of the high density. Finally, as the peak of the synchrotron SED is at high frequencies, the entire observed spectrum lies above the cooling frequency, the first time (as far as we are aware) that this has been reported. The powerful X-ray emission from AT2018cow also Compton-heated the surrounding medium to such a high temperature as to wipe out free-free absorption (commonly invoked to absorb early low-frequency radio emission from supernovae). In the case of AT2018cow, the cm-wavelength spectrum is set just by synchrotron self-absorption.

Extraordinarily, despite intense multiwavelength examination, AT2018cow only deepened the mystery surrounding fast-luminous transients. Its rapid evolution and location in the spiral arm of a star-forming galaxy suggests a massive-star origin. However, the UVOIR spectra resemble those predicted for a tidal disruption event: the disruption of a main sequence star or a white dwarf by an intermediate-mass black hole (Kuin et al. 2018; Perley et al. 2018). The luminous radio and millimeter emission, together with luminous and highly-variable X-ray emission, suggest continuous energy injection by an accreting black hole or a highly-magnetized neutron star (Margutti et al. 2018; Ho et al. 2018). This could happen both in a supernova and in a tidal disruption event.

Although AT2018cow is a singular transient, the millimeter properties may not be so unusual. In fact, a key result of our study is that the circumstances that gave rise to long-lived luminous millimeter emission in AT2018cow were also seen in other classes of explosions: in particular, there have been supernovae with large energies and high ambient densities, but which were only observed at centimeter wavelengths (e.g., SN 2007bg, SN 2003bg, and SN 2003L). As shown in the right panel of **Figure 1**, their late-time centimeter-wavelength behavior is very similar to that of AT2018cow. Another promising class for future millimeter study is that of energetic supernovae observed to accompany low-luminosity gamma-ray bursts. Only one member of this class (the archetype, SN 1998bw) was observed at millimeter wavelengths, and this yielded a luminous detection (see left panel of **Figure 1**). Thus, there are at least two classes of supernovae that may be luminous millimeter transients if they are observed by millimeter telescopes at early times. In the next few years, optical wide-field surveys will uncover new members of these classes, and (as for AT2018cow) millimeter observations will be essential for measuring the early evolution of the explosion and tracing the structure of the ambient medium. Thus motivated, we urge systematic millimeter observations dedicated to the pursuit of optical transients.

REFERENCES

- Arcavi, I., Wolf, W. M., Howell, D. A., et al. 2016, ApJ, 819, 35
- Arnett, W. D. 1979, ApJL, 230, L37
- Chevalier, R. A. 1976, ApJ, 207, 872
- Chevalier, R. A. 1998, ApJ, 499, 810
- Colgate, S. A., & McKee, C. 1969, ApJ, 157, 623
- Drout, M. R., Chornock, R., Soderberg, A. M., et al. 2014, ApJ, 794, 23
- Grassberg, E. K., Imshennik, V. S., & Nadyozhin, D. K. 1971, Ap&SS, 10, 28
- Ho, A. Y. Q., Phinney, E. S., Ravi, V., et al. 2018, arXiv:1810.10880
- Kasen, D. 2017, Handbook of Supernovae, ISBN 978-3-319-21845-8. Springer International Publishing AG, 2017, p. 939, 939
- Kuin, N. P. M., Wu, K., Oates, S., et al. 2018, arXiv:1808.08492
- Margutti, R., Metzger, B. D., Chornock, R., et al. 2018, arXiv:1810.10720
- Nakar, E., & Sari, R. 2010, ApJ, 725, 904
- Perley, D. A., Mazzali, P. A., Yan, L., et al. 2018, arXiv:1808.00969
- Prentice, S. J., Maguire, K., Smartt, S. J., et al. 2018, ApJL, 865, L3
- Pursiainen, M., Childress, M., Smith, M., et al. 2018, MNRAS, 481, 894
- Rest, A., Garnavich, P. M., Khatami, D., et al. 2018, Nature Astronomy, 2, 307
- Rivera Sandoval, L. E., Maccarone, T. J., Corsi, A., et al. 2018, MNRAS, 480, L146
- Smartt, S. J., Clark, P., Smith, K. W., et al. 2018, The Astronomer's Telegram, 11727
- Tanaka, M., Tominaga, N., Morokuma, T., et al. 2016, ApJ, 819, 5
- Whitesides, L., Lunnan, R., Kasliwal, M. M., et al. 2017, ApJ, 851, 107

SUBMILLIMETER ARRAY OBSERVATIONS OF EXTENDED CO (J=2–1) EMISSION IN THE INTERACTING GALAXY NGC 3627

Charles J. Law[1], Qizhou Zhang[1], Luca Ricci[2], Glen Petitpas[1], Maria J. Jiménez-Donaire[1], Junko Ueda[1], Xing Lu[3], and Michael M. Dunham[4]

In addition to being fascinating in their own right, nearby galaxies are crucial to the understanding of galaxy evolution and interactions. They allow us to directly resolve the region around active nuclei and individual star-forming clouds over the full galactic disk. This comprehensive view allows us to connect the small-scale physics of the interstellar medium and star formation to the disk-wide processes that drive galaxy evolution. Most previous extragalactic molecular gas studies have used the ^{12}CO(J=1-0) line to trace molecular gas mass. With the recent abundance of ^{12}CO(J=2-1) observations, a more detailed understanding of the ^{12}CO(J=2-1)/^{12}CO(J=1-0) line ratio ($R_{21/10}$) is required to compare results across the literature. Adding to the urgency of this, ^{12}CO(J=2-1) and J=3-2 lines are now regularly observed from z ~ 1 to 3 galaxies (Tacconi et al. 2013, 2018), where they are used to trace the total gas supply. A quantitative understanding of the variation in the $R_{21/10}$ line ratio is required to discern what is driving observed changes in $R_{21/10}$ on galaxy-wide scales as well as to make rigorous statements about the behavior of molecular gas across galaxy populations.

Observations of the ^{12}CO(J=2-1) distribution in the very outer arms and inter-arm regions of a spiral galaxy such as NGC 3627 are particularly informative. Typical spiral galaxies do not contain conspicuous ^{12}CO(J=2-1) emission in the arm and inter-arm regions as observed in NGC 3627. Comparing this gas tracer with the large existing set of complementary data for NGC 3627 provides a unique opportunity to study gas conditions in a very wide range of environments. Due to its close proximity (11 Mpc) and high inclination (61°), NGC 3627 is an attractive candidate for investigating gas dynamics

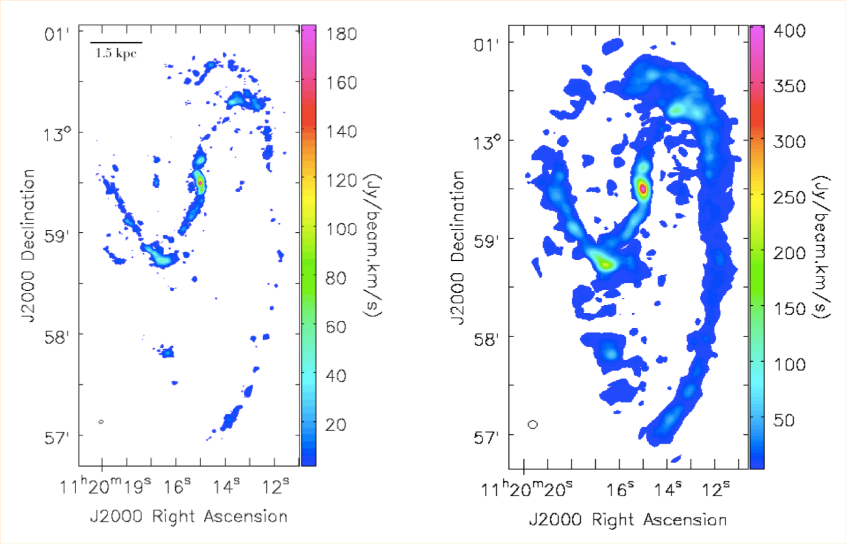


Figure 1: Left: Integrated intensity map of the ^{12}CO(J=2-1) line emission in NGC 3627. The image was made with natural weighting and no *uv*-taper. The beam size is 2.25 x 1.75 arcsec, shown in the lower left corner, which corresponds to physical scales of ~100 pc. **Right:** Integrated intensity of SMA+IRAM 30 m combined map of the ^{12}CO(J=2-1) line emission in NGC 3627. Substantially more diffuse emission, especially in the spiral arms, can be seen in this map and the beam size is 5.39 x 4.87 arcsec. Typical 1σ rms noise levels are 14 mJy beam^{-1} and 30 mJy beam^{-1} per 20 km s^{-1} channel for the non-tapered and combined maps, respectively.

[1] CfA, [2] Cal State, Northridge, [3] NAOJ, [4] SUNY Fredonia

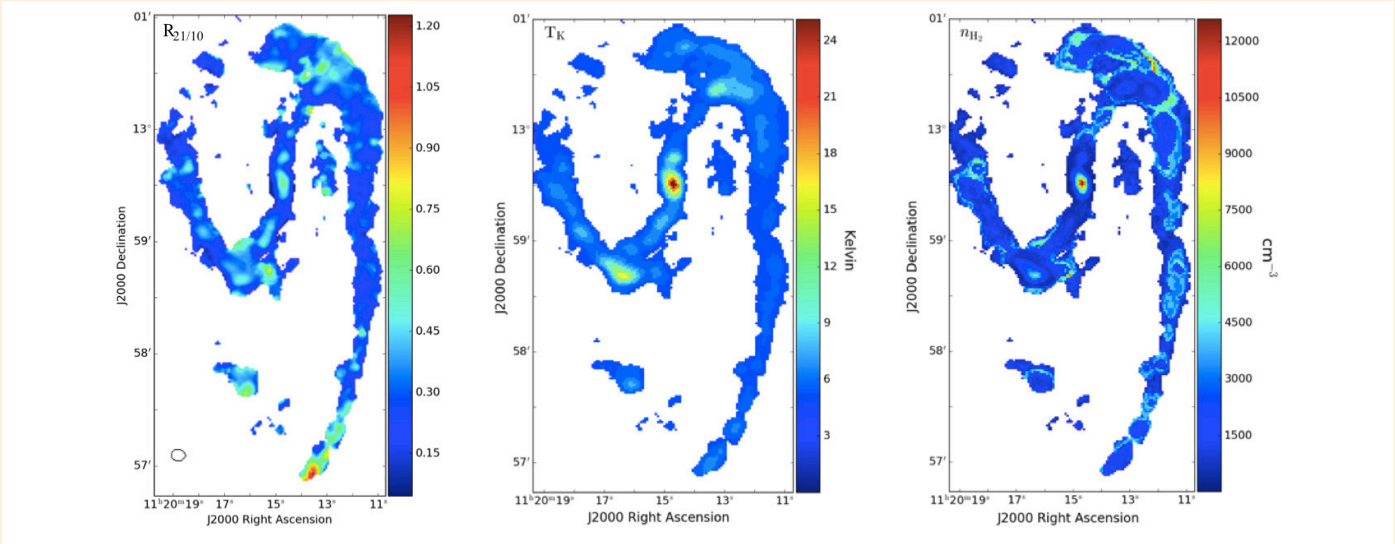


Figure 2: Left: Line ratio map of $R_{21/10}$ = $^{12}CO(J=2-1)$ / $^{12}CO(J=1-0)$ with a 3σ threshold. Combined SMA+IRAM 30 m and BIMA+NRAO 12 m data were used for the J=2-1 and J=1-0 line emission, respectively. **Middle:** Kinetic temperature map, derived from RADEX modeling. **Right:** H_2 number density map, derived from RADEX modeling.

and galactic evolution. By obtaining new SMA observations at 230 GHz in the sub-compact, compact, and extended configurations, we were able to map line emission from $^{12}CO(J=2-1)$ at molecular cloud scales (~100 pc) across the entire galaxy. To recover more extended emission, *uv*-tapered maps were also produced and then combined with single-dish observations from the IRAM 30 m telescope (Leroy et al. 2009) (see **Figure 1**).

Prominent $^{12}CO(J=2-1)$ emission is seen in the dense nuclear and bar-end regions as well as throughout the more tenuous spiral arms and inter-arm regions. The gas exhibits large velocity gradients both across the central nuclear bar (~250 km s^{-1}) and the extended spiral arms (~400 km s^{-1}). High resolution (~1”) imaging of the nuclear region reveals small-scale structures in the form of two emission maxima offset from a central peak, which is consistent with previous IRAM PdBI observations (Casasola et al. 2011). Unresolved emission from the J=2-1 line of the ^{13}CO isotopologue was only detected in the southern bar end, central region, and an ‘isolated clump’ in the south of NGC 3627. The $^{12}CO(J=2-1)$/ $^{13}CO(J=2-1)$ line ratios were found to be ~50% lower in the denser, hotter nuclear region compared to the more diffuse, cooler southern bar end, which is likely a critical density or optical depth effect, but could potentially be probing changes in $^{12}C/^{13}C$ abundance.

To better understand the local excitation conditions, we computed $R_{21/10}$ using our SMA observations and archival BIMA SONG observations (Regan et al. 2001; Helfer et al. 2003) that were single-dish corrected using $^{12}CO(J=1-0)$ data from the NRAO 12 m telescope. **Figure 2** shows the resulting line ratio map. Our data reveal high line ratios of ~0.5-0.8 toward the LINER/Sy2 nucleus as well as the northern and southern bar ends, which are likely the result of nuclear starburst and bar-arm interactions, respectively (Warren et al. 2010; Beuther et al. 2017). The highest line ratios (up to 1.2) were found in the southern clump of emission and in the southernmost tip of the extended western arm. Both of these regions correspond to hot spots in the *Spitzer* 8 μm map (Kennicutt et al. 2003) and are known to host active star formation. Overall, the line ratio map appears clumpy with hot spots of elevated gas ratios appearing throughout the galaxy.

Using a RADEX analysis (van der Tak et al. 2007; Lu et al. 2017), we derived kinetic temperature (T_K) and H_2 number density (n_{H2}) maps of NGC 3627. As shown in **Figure 2**, kinetic temperatures range from ~5-10 K in the spiral arms to ~25 K in the nuclear region. The number densities exhibit a similar trend, spanning more than an order of magnitude from ~400-1000 cm^{-3} in the spiral arms to ~12,500 cm^{-3} in the nucleus. While these T_K values are consistent with those derived using CO line ratios in other external galaxies (e.g., NGC 2903, Muraoka et al. 2016), we find n_{H2} values, especially those that correspond to the center and bar ends of NGC 3627, that are an order of magnitude in excess of those reported for NGC 2903 and NGC 604 in M33 (Muraoka et al. 2012). If we assume a typical vertical FWHM of CO gas (Yim et al. 2011), we estimate a total H_2 mass, which is about 50% larger than previous mass estimates using $^{12}CO(J=1-0)$ observations (Helfer et al. 2003; Kuno et al. 2007).

We investigated potential correlations across different spatial regions in NGC 3627 to examine the dependence of star formation efficiency (SFE) on the derived physical parameters T_K and n_{H2}. Using SFE values from Watanabe et al. (2011), we identify a tentative SFE-T_K correlation but do not find any correlation between SFE and n_{H2}. The absence of the latter correlation is somewhat unexpected, since molecular gas density is thought to control spatial variations in SFE (e.g., Muraoka et al. 2016; Koyama et al. 2017). However, being an interacting galaxy, NGC 3627 may follow a more complex scaling relationship between n_{H2} and SFE. In fact, the lack of SFE-n_{H2} correlation is consistent with recent ALMA observations by Gallagher et al. (2018), who find no correlation between the normalized star formation rate and dense gas fraction in NGC 3627. These correlations (and lack thereof) should be treated as somewhat speculative in nature and, while interesting in their own right, deserve additional follow-up in NGC 3627 and across a larger set of galaxies with observations of large-scale, multiline ^{12}CO emission.

Overall, NGC 3627 remains a popular and scientifically-rich target for nearby galaxy studies, having been the subject of numerous recent multiline surveys with both single dish telescopes (e.g., Cormier et al. 2018) and interferometers such as the SMA and ALMA (e.g., Gallagher et al. 2018, Sun et al. 2018). These high angular resolution studies of molecular gas in nearby galaxies allow us to bridge the gap in scale between individual molecular clouds studied in the Milky Way and galaxy averages used in previous studies. Such observations also reveal distinct dynamical regions with varying physical conditions and help us better understand the physical drivers of variations in line ratios and star formation efficiencies.

Special Acknowledgement: C. Law would like to acknowledge that his initial involvement with this project was the result of Harvard College's Astronomy 191 research course run by John Kovac. One of the half-semester projects involved reducing and analyzing a few pointings of SMA data on NGC 3627, which provided him (and other undergraduate astronomy students) initial exposure to radio interferometry and sub-mm science. C. Law would also like to highlight the careful and helpful mentorship of L. Ricci (an SMA postdoc at the time) and Q. Zhang throughout and beyond this course. Astronomy 191 provides undergraduates a chance to interact with world-class radio observations and would not be possible without the contributions of SAO astrophysicists and SMA postdocs who volunteer their time to help supervise students.

REFERENCES

- Beuther, H., Meidt, S., Schinnerer, E., Paladino, R., & Leroy, A. 2017, A&A, 597, A85
- Casasola, V., Hunt, L. K., Combes, F., García-Burillo, S., & Neri, R. 2011, A&A, 527, A92
- Cormier, D., Bigiel, F., Jiménez-Donaire, M. J., et al. 2018, MNRAS,475, 3909
- Gallagher, M. J., Leroy, A. K., Bigiel, F., et al. 2018, ApJ, 858, 90
- Helfer, T. T., Thornley, M. D., Regan, M. W., et al. 2003, ApJS, 145, 259
- Kennicutt, R. C., Jr., Armus, L., Bendo, G., et al. 2003, PASP, 115, 928
- Koyama, S., Koyama, Y., Yamashita, T., et al. 2017, ApJ, 847, 137
- Kuno, N., Sato, N., Nakanishi, H., et al. 2007, PASJ, 59, 117
- Leroy, A. K., Walter, F., Bigiel, F., et al. 2009, AJ, 137, 4670
- Lu, X., Zhang, Q., Kauffmann, J., et al. 2017, ApJ, 839, 1
- Muraoka, K., Tosaki, T., Miura, R., et al. 2012, PASJ, 64, 3
- Muraoka, K., Sorai, K., Kuno, N., et al. 2016, PASJ, 68, 89
- Regan, M. W., Thornley, M. D., Helfer, T. T., et al. 2001, ApJ, 561, 218
- Sun, J., Leroy, A. K., Schruba, A., et al. 2018, ApJ, 860, 172
- Tacconi, L. J., Neri, R., Genzel, R., et al. 2013, ApJ, 768, 74
- Tacconi, L. J., Genzel, R., Saintonge, A., et al. 2018, ApJ, 853, 179
- van der Tak, F. F. S., Black, J. H., Schöier, F. L., Jansen, D. J., & van Dishoeck, E. F. 2007, A&A, 468, 627
- Warren, B. E., Wilson, C. D., Israel, F. P., et al. 2010, ApJ, 714, 571
- Watanabe, Y., Sorai, K., Kuno, N., & Habe, A. 2011, MNRAS, 411, 1409
- Yim, K., Wong, T., Howk, J. C., & van der Hulst, J. M. 2011, AJ, 141, 48

MULTIWAVELENGTH LIGHT CURVES OF TWO REMARKABLE SAGITTARIUS A* FLARES

G. G. Fazio,[1] J. L. Hora,[1] G. Witzel,[2] S. P. Willner,[1] M. L. N. Ashby,[1] F. Baganoff,[3] E. Becklin,[2] S. Carey,[4] D. Haggard,[5] C. Gammie,[6] A. Ghez,[2] M. A. Gurwell,[1] J. Ingalls,[4] D. Marrone,[7] M. R. Morris,[2] H. A. Smith[1]

Sagittarius A* (Sgr A*), the supermassive black hole (SMBH) at the center of our Milky Way galaxy, is 100 times closer than any other SMBH and is therefore a prime candidate to study the electromagnetic radiation generated by mass accretion flow onto a black hole and/or a related jet. Sgr A* has been targeted for decades in attempts to learn about SMBH physics from its variability at many wavelengths. Rapid fluctuations have been detected at soft and hard X-ray bands (Baganoff et al. 2001; Nowak et al. 2012; Neilson et al. 2013, 2015; Barriére et al. 2014; Ponti et al. 2015) and at near-infrared (NIR) wavelengths (Genzel et al. 2003; Ghez et al. 2004; Hornstein et al. 2007; Witzel et al. 2012, 2018; Hora et al. 2014), where the extinction to the Galactic center is relatively low. Slower and lower-amplitude variability has been seen at submillimeter (submm), millimeter (mm), and radio wavelengths (Mauerhan et al. 2005; Macquart & Bower 2006; Marrone et al. 2008; Yusef-Zadeh et al. 2006b; Brinkerink et al. 2015). Disentangling the power source and emission mechanisms of the variability is a central challenge to our understanding of accretion flows around SMBHs at the cores of normal galaxies. The chief barrier to progress is the absence of a sufficient sample of simultaneous, multiwavelength variability measurements, their correlations being key to discriminating among emission models (Neilson et al. 2015; Dibi et al. 2016; Connors et al. 2017).

Following the discovery of NIR and X-ray variability, coordinated observing campaigns over a range of wavelengths were initiated. However, it has proven very difficult to obtain a sufficient number of simultaneous flares at X-ray and NIR wavelengths to determine their relationship (Eckart et al. 2006b, 2008; 2012; Yusef-Zadeh et al. 2006a, 2012; Hornstein et al. 2007; Marrone et al. 2008; Dodds-Eden et al. 2009; Ponti et al. 2017). Strong X-ray flares always showed a coincident NIR maximum, but there were numerous NIR maxima with no X-ray counterpart (Eckart et al. 2004; Hornstein et al. 2007; **Figure 1**).

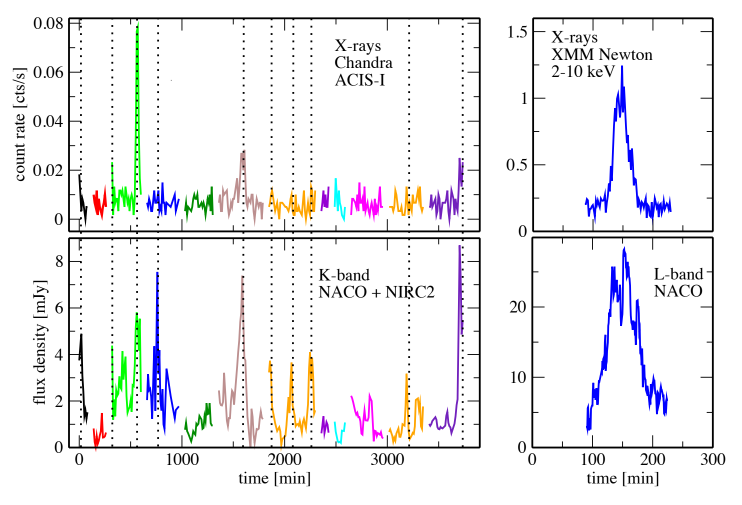


Figure 1: Left: a total of ~58 hr of simultaneous observations with VLT/NACO at 2.18 µm and Keck/NIRC2 at 2.12 µm and Chandra X-ray Observatory/ACIS-I at 2–8 keV is displayed. The minimum observed flux density of 3.05 mJy was subtracted from the NIR data before plotting. Observations were taken in separate 3–7 hr intervals as shown by the colors but are merged here on a continuous time axis. Vertical lines mark NIR peaks. This graph was provided by Zhiyuan Li. **Right**: the X-ray (2–10 keV; XMM-Newton) and the L-band (3.8 µm; VLT/NACO) data from the very bright 2007 April 4 flare (Dodds-Eden et al. 2009).

[1] Harvard-Smithsonian Center for Astrophysics, 60 Garden St., MS-65, Cambridge, MA 02138; [2] University of California, Los Angeles, 475 Portola Plaza, Los Angeles, CA 90095; [3] Massachusetts Institute of Technology, 77 Massachusetts Ave, 37-555, Cambridge, MA 02139; [4] California Institute of Technology, MS 314-6, Pasadena, CA 91125; [5] McGill University, 3600 University Street, Montreal, QC, H3A 2T8; [6] University of Illinois - Urbana-Champaign, 1002 West Green Street, Urbana, IL 61801; [7] University of Arizona, 933 North Cherry Avenue, Tucson, AZ 85721

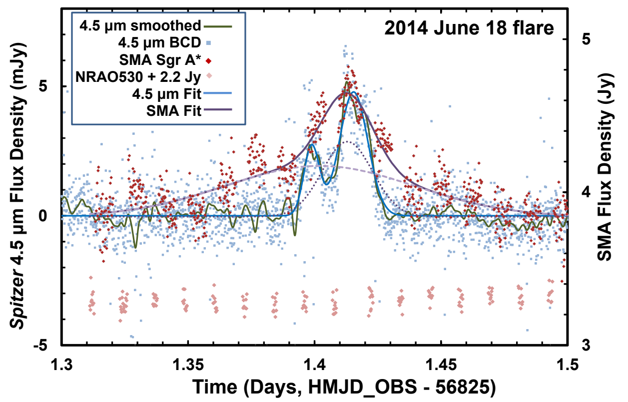


Figure 2: 2014 June 18 joint observations of a double-peaked flare from Sgr A* by Spitzer/IRAC at 4.5 µm (blue dots and green smoothed line, scale on the left ordinate) and the SMA at 875 µm (red dots, scale on the right ordinate). The SMA calibrator (NRAO 530) flux density (shown in light red at the bottom) is ~1 Jy (a constant of 2.2 Jy was added to place the data on the right ordinate scale). The blue smoothed line is the two-Gaussian curve fit to the 4.5 µm data. Dotted and dashed purple lines show two Gaussian curves fitting the SMA submillimeter data, and the solid purple line shows their sum.

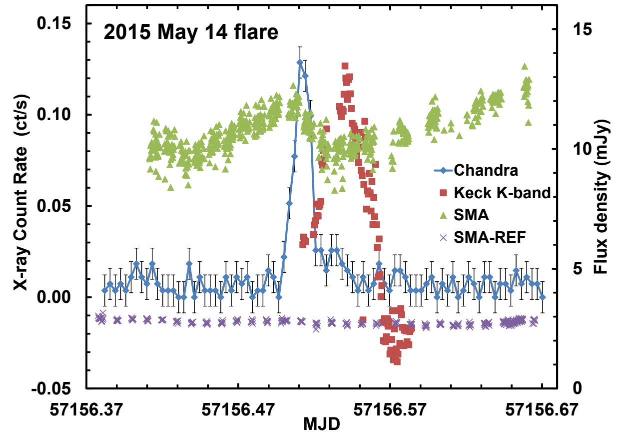


Figure 3: 2015 May 14 observations of a single-peaked flare from Sgr A*. Red squares show the Keck 2.12 µm data (scale on right ordinate), green triangles the 1.32 mm SMA data (scale is 500× the right ordinate, i.e., peak flux density is ~6 Jy), and blue points the Chandra 2–8 keV data (left ordinate). The X-ray light curve is summed over 300 s bins, and Poisson error bars on the X-ray count rate are shown by black error bars. The SMA calibrator (NRAO 530) flux density (~1.4 Jy), scaled the same as for Sgr A*, is shown by purple crosses.

Associating radio/submm flares with NIR and X-ray flares has been more difficult than establishing the NIR/X-ray connection. The first observations of a flare of Sgr A* detected at submm, NIR, and X-ray wavelengths were reported by Marrone et al. (2008) using the Submillimeter Array (SMA). However, given the multi-hour duration of typical submm brightening events, the short durations of submm observations (nearly all less than 8 h), and the infrequency of submm brightening events, there is some chance that the submm events are only coincidentally related to the shorter-wavelength activity. Morris et al. (2012) summarized the reported time lags between NIR and millimeter/submm peaks for 7 events. The delays ranged from 90 minutes to 200 minutes, with one possible exception, but on the average, the delay appeared to be ~150 min.

The origin of the NIR and X-ray brightening fluctuations remains unknown, but the rapid modulation suggests the emission source most likely originates just outside the event horizon. Study of the light curves may therefore provide insight into the structure and conditions in the inner accretion regions. (See review by Morris et al. 2012.) The near-simultaneity of the NIR and X-ray brightness fluctuations suggests a common origin, but the fact that not all NIR peaks are accompanied by X-ray flares suggests that either there are two physical origins for the NIR events or that the physical mechanism for the flares has two different observational manifestations, e.g., different flares arise from electron energy distributions having different high-energy cutoffs, so some have enough energy to emit X-rays and some do not.

Despite the past multiwavelength monitoring over several years, Sgr A* can still surprise us. Our new paper (2018 ApJ 864, 58) presents observations of two flares that seem to violate the previous patterns in the relative timing of submm/NIR/X-ray flares from Sgr A*. One of these flares provides the first evidence of near time coincidence between a NIR and submm outburst, while the second event is the first example of an X-ray flare followed by a submm outburst followed by a NIR peak, all within ~1 hr. The first was on **2014 June 17–18** with the *Spitzer Space Telescope*/IRAC at 4.5 µm and the Submillimeter Array (SMA) at 343 GHz (875 µm). The second was on **2015 May 14** with the Keck telescope at 2.12 µm, the SMA at 227 GHz, and the *Chandra X-ray Observatory* at 2–8 keV.

The **2014 June 18 flare (Figure 2)**, with the smoothed peaks of the NIR and submm fluxes within ~4 min of each other, and the fact that the submm flux rises earlier that the NIR flux, differs from previous results that the submm flares follow concurrent NIR and X-ray outbursts with time delays of ~150 minutes. This flare sequence seems to rule out the synchrotron-self-Compton/expanding blob model and/or the jet model as its origin. The near-simultaneous NIR and submm peaks may be consistent with the Chan et al. (2015) GRMHD models invoking strong lensing. Connecting the X-ray/NIR models to the submm/radio models has always been difficult. With 32 hours of NIR/submm simultaneous observations from 2014 to 2017, it is possible this event is a random coincidence, even though the peak emissions of the two curves coincide within ~4 minutes.

The **2015 May 14 flare (Figure 3)** is unique in that the submm flux density peaks first, followed ~28 minutes later by the X-ray peak, with the NIR peak emission occurring ~66 minutes after the submm peak. No model we are aware of explains this sequence. However, the NIR observations began only at the peak of the X-ray flare, at which time the NIR flux was already elevated over the noise level. Because NIR events are often multi-peaked, a second, smaller NIR peak could have been associated with the X-ray flare with the subsequent, larger NIR peak being one with no X-ray association. In addition, Sgr A* is always varying at mm wavelength about a mean level of ~3 Jy. Again, there is the chance that in the case of this flare, the X-ray, NIR, and submm flux increases are only coincidently related to each other.

The temporal structure of the two flare events shown in this paper implies that current theoretical models cannot explain the origin of the multiwavelength variability of Sgr A*. There is a continued and important need for long-term, coordinated, and precise multiwavelength observations of Sgr A* in order to characterize the full range of flare behaviors. The X-ray spectral index and its possible correlation with the characteristics of the NIR or sub-mm activity (peak intensity, time lags, peak duration, rise or fall times) might hold a clue to both the X-ray emission mechanism and to the underlying cause of the variability. Future coordinated monitoring should endeavor to go all the way to cm-wave radio in order to determine the wavelength dependence of the phase lags, as the results in this paper show that our present view of the physical processes at work and their wavelength dependences are far from being understood. There is also a need for more detailed and more varied models of strongly sub-Eddington accretion onto supermassive black holes.

REFERENCES

- Baganoff, F. K., et al. 2001, Nature, 413, 45
- Barrière, N. M. et al. 2014, ApJ, 786, 46
- Brinkerink, C. D. et al. 2015, A&A, 576, 41
- Chan, C. et al. 2015, ApJ, 812, 103
- Connors, R. M., et al. 2017, MNRAS, 466, 4121
- Dibi, S. et al. 2016, MNRAS, 461,552
- Dodds-Eden, K. et al., 2009, ApJ, 698, 676
- Eckart, A. et al. 2004, A&A, 427, 1
- Eckart, A. et al. 2006b, A&A, 455, 1
- Eckart, A. et al. 2008, A&A, 492, 337
- Eckart, A. et al. 2012, A&A, 537, A52
- Genzel, R. et al. 2003, Nature, 425, 934
- Ghez, A., et al. 2004, ApJ, 601, L159
- Hora, J. et al. 2014, ApJ, 793, 120
- Hornstein et al. 2007, ApJ, 667
- Macquart, J.-P. & Bower, G. C. 2006, ApJ, 646, 111
- Mauerhan, J. C., et al. 2005, ApJ, 623, 25
- Marrone, D. P. et al. 2008, ApJ, 682, 373
- Morris, M. R. et al. 2012, RAA, 12, 995
- Neilsen, J., et al. 2013, ApJ, 774, 42
- Neilsen, J., et al. 2015, ApJ, 799, 199
- Nowak, M. A., et al. 2012, ApJ, 759, 95
- Ponti, G., et al. 2015, MNRAS, 454, 1525
- Ponti, G., et al. 2017, MNRAS, 468, 2447
- Witzel, G., Eckart, A., Bremer, M., et al. 2012, ApJS, 203, 18
- Witzel, G., et al. 2018, accepted for publication in ApJ
- Yusef-Zadeh, F. et al. 2006a, ApJ, 644, 198
- Yusef-Zadeh, F. et al. 2006b, ApJ, 650, 189,
- Yusef-Zadeh, F. et al. 2012, AJ, 144, 1

A SUBMILLIMETER BURST OF S255IR SMA1: THE RISE AND FALL OF ITS LUMINOSITY

Sheng-Yuan Liu (ASIAA), Yu-Nung Su (ASIAA), Igor Zinchenko (IAP/RAS), Kuo-Song Wang (ASIAA), Yuan Wang (MPIA)

Temporal photometric variations associated with young low-mass stars of Class I or II, such as those FU Orion-type (FUor) and EX Lup-type (EXor) events, have been observed in the optical to mid-infrared (MIR) wavelengths (Audard et al. 2014). Accompanied by spectroscopic signatures of hot disks and winds, these phenomena are generally interpreted as accretion events of star-disk systems with elevated rates. That is, instead of falling through steady flows to the central stars, circumstellar material fragments and accretes sporadically due to instabilities developed in the disks.

It is conceivable that at an earlier, more embedded (Class 0/I) evolutionary stage, Young Stellar Objects (YSOs) may have been subjected to similar episodic accretion events. Due to envelope obscuration, however, such phenomenon may not be visible in the optical or infrared (IR) but possibly detectable at longer (far-infrared (FIR) to millimeter) wavelengths (Johnstone et al. 2013). Indeed, HOPS 383, a Class 0 protostar, was the very first example reported with a brightening event not only in the MIR but also in the submillimeter bands (Safron et al. 2015). Furthermore, recent submillimeter observations of YSOs in nearby molecular clouds successfully revealed, for the first time through a monitoring program, a luminosity flaring event toward a Class I YSO in the Serpens cloud (Yoo et al. 2017). Molecular line imaging experiments, probing the thermal history of envelopes around embedded YSOs, also provided indirect indications of luminosity flaring (Jørgensen et al. 2013).

Do similar luminosity variation phenomena occur during the massive star formation process? There appears to be growing evidence pointing to a positive answer. For example, S255, a massive cluster formation region with a bolometric luminosity of several 10^4 $L_\odot$at a distance of 1.78 kpc (Burns et al. 2016), was first detected with methanol maser flares (Fujisawa et al. 2015). Subsequent observations in the near-infrared (NIR) witnessed brightening of not only the NIR continuum but also atomic and molecular lines (Caratti o Garatti et al. 2017). Observations of the 6.7 GHz methanol maser at high angular resolutions revealed the large extent of

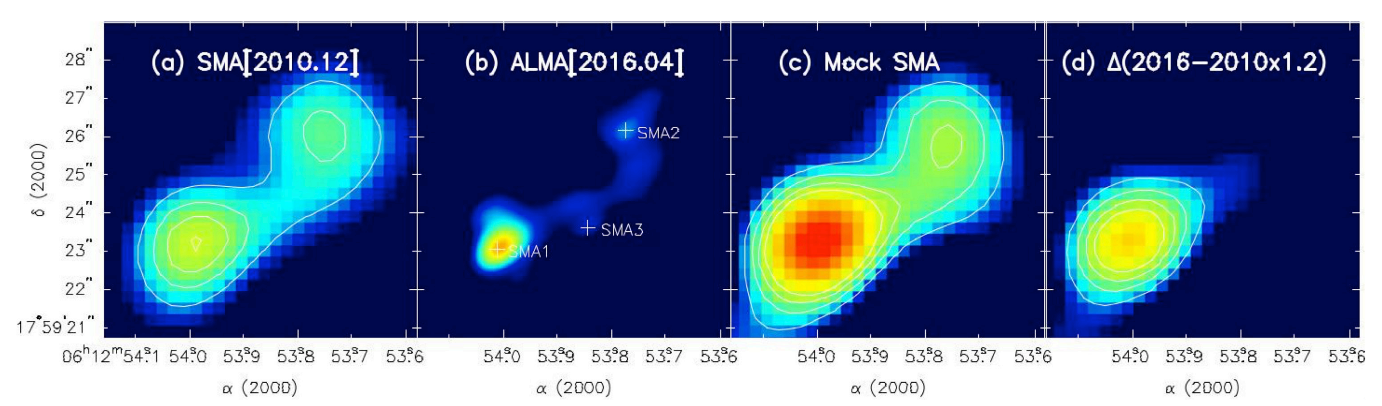


Figure 1: 900 μm continuum image of S255IR (a) observed in 2010 December by SMA at an angular resolution of ~2″.0. (b) Observed in 2016 April by ALMA at an angular resolution of ~0″.6. (c) Made through mock SMA observations using panel (b) as the sky model. (d) The difference map made by first scaling panel (a) by 1.2 and subtracting that from panel (c). Contour levels in (a), (c) and (d) are the same, so is the false color scheme.

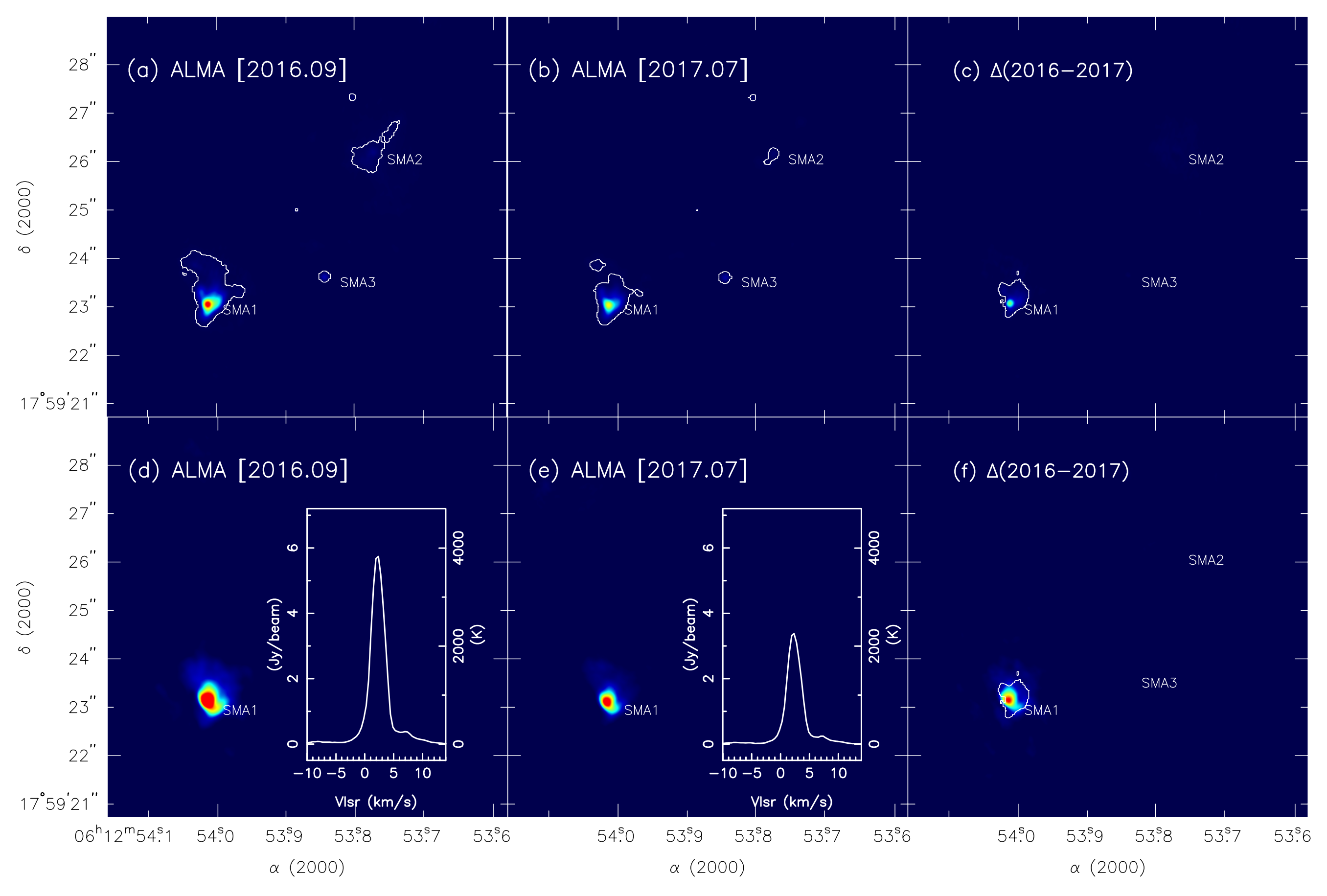


Figure 2: **(a)** 900 μm continuum image of S255IR observed in 2016 September by ALMA at an angular resolution of 0″.14. **(b)** Same as **(a)** but observed in 2017 July by ALMA. **(c)** The difference map made by subtracting **(b)** from **(a).** The contour at 5-σ level marks the boundary of regions with significant emission and SMA1–3 are labeled in panel **(a)-(c)**. **(d)** Integrated intensity map of the 349.1 GHz CH_3OH 14_1-14_0A^+ maser emission observed by ALMA in 2016 September. An inset in the panel displays the CH_3OH spectra at its peak position. **(e)** Same as **(d)** but observed by ALMA in 2017 July. **(f)** The difference CH_3OH maser map made by subtracting **(e)** from **(d)**. The contour delineates the region with excess 900 μm continuum emission shown in **(c)**.

the masing region and further associated the flaring most likely with the increasing NIR continuum (Moscadelli et al. 2017). NGC 6334(I), another massive star-cluster-forming site, also spotted with an increase of its submillimeter continuum (Hunter et al. 2017). Follow-up observations confirmed the emergence of new methanol masers as a result of the luminosity burst (Hunter et al. 2018).

We have previously reported a series of studies of S255IR using the Submillimeter Array (SMA). While NIR imaging revealed a cluster of YSOs associated with the molecular gas ridge sandwiched by two nearby H II regions (Ojha et al. 2011), submillimeter continuum observations indicated an overall molecular gas of around 300–400 $M_\odot$ in this region, and disclosed at higher angular resolution several dense clumps residing in the complex (Wang et al. 2011; Zinchenko et al. 2012, 2015). In particular, the dominant source, S255IR SMA1, coinciding with the NIR source S255IR NIRS3, is associated with a prominent molecular bipolar outflow and a rotating disk-like structure (Zinchenko et al. 2012, 2015). The putative disk, perpendicular to the outflow in its orientation, probably is viewed closely edge-on (Boley et al. 2013). Based on its luminosity and the maser kinematics, the mass of the central YSO is estimated to be ~20 $M_\odot$ (Zinchenko et al. 2015).

Fortuitously, our continuing investigation of S255IR lead to three epochs of observations with the Atacama Large Millimeter and submillimeter Array (ALMA) at around the same period when the maser flare event occurred, enabling a time-series comparison of this object. Presented in **panels (a)–(b) in Figure 1** are the 900 μm continuum images of S255IR observed with SMA in 2010 December as reported in Zinchenko et al. (2015) and with ALMA in 2016 April. At a lower (SMA) resolution **(panel (a))**, two prominent features, S255IR SMA1 and SMA2, are resolved apart. S255IR SMA3 is further revealed in the higher resolution ALMA image **(panel (b))**. We attempted to compare equally the two observations by making mock SMA observations through re-sampling and re-imaging the ALMA map **(panel (b))** using the uv-coverage achieved by the 2010 SMA observation, similar to the approach adopted in Hunter et al. (2017). In the resulting mock image **(Figure 1 (c))**, S255IR SMA1 and SMA2 remain visible. It is evident that SMA1 and SMA2 show disparate contrasts in the two (2010 and 2016) epochs, hinting on flux density variation in SMA1 and/or SMA2 during this period. Displayed in **Figure 1(d)** is the difference map between **panels (a) and (c)**, if we assume that SMA2 has not changed. A compact excess emission feature is visible in this difference map **(Figure 1(d))** toward SMA1 while no obvious residual remains toward SMA2. Given prior evidences of a flaring event associated with SMA1 in mid 2015, the above excess emission is most probably associated with the flare event. Both the intensity and the flux density of SMA1 roughly doubled in 2016 as compared to 2010.

We display in **Figures 2(a)–(b)** the high (0″.14) resolution 900 μm continuum observed in 2016 September and 2017 July. For comparing these two observations, we generated synthesis images by using data within a common uv-range well shared by both observations and then restoring the final resolution to a circular 0″.14 beam. **Figure 2(c)** is the difference map made by subtracting **panel (b)** from **panel (a).** While emission features such as SMA2 and SMA3 are canceled out, excess emission stands out noticeably at S255IR SMA1. Both its peak intensity and its flux density decreased during this period.

Zinchenko et al. (2017) reported a nonthermal methanol emission line at 349.1 GHz, reaching a brightness temperature of 3900 K (5.9 Jy/beam) at an angular resolution of ~0″.12. The line feature was assigned as a newly discovered maser associated with the CH_3OH 14_1–14_0 A^{-+} transition, likely a Class II CH_3OH maser predominantly excited by IR radiation field. In **Figure 2(d)-(e)** the spectra at the maser peak position and the integrated maser emission in 2016 September and 2017 July are presented. The peak intensity has discernibly fallen to 2380 K (3.6 Jy/beam) in 2017 July, a reduction of 40%. The difference map of the integrated intensity **(Figure 2(e))** indicates that the excess CH_3OH emission region falls within the extent of the (excess) continuum emission.

The comparison between our SMA and ALMA observations indicated a factor of 2 increase in both the intensity and flux density of 900 μm continuum toward SMA1 in early 2016. ALMA observations further witnessed, for the first time, the waning of this continuum emission as well as CH_3OH maser in mid 2017. Whether the dust continuum emission is optically thick or thin, its brightness and flux density variation is reflecting most likely a dust temperature change. Such a dust temperature elevation suggests an overall bolometric luminosity increase by a factor of about 16 in S255IR SMA1 as total emission of the dust envelope scales with temperature to the 4th power (Hunter et al. 2017). The dimming submillimeter continuum in 2016–2017, correspondingly a decreasing of dust temperature by 40%, also plausibly reflects a reduced radiation field, as well as a factor of 8 decrease in its luminosity.

Based on the propagation of the light echo, Caratti o Garatti et al. (2017) hypothesized that the S255IR SMA1 burst event occurred in mid-June of 2015. This appears consistent with the first report of 6.7 GHz methanol maser flaring seen from early July of 2015 as reported by Fujisawa et al. (2015). Direct NIR imaging in 2015 November disclosed brightening of the region as compared to the pre-burst image taken in 2009 (Caratti o Garatti et al. 2017). The extended K_S-band emission is the reprocessed light from hot dust presumably heated by the central star and escaped from the outflow cavity. Our ALMA image taken in 2016 April also exhibits boosted submillimeter intensity toward SMA1 as compared to that of 2010. This emission presumably originates from the dusty disk and/or envelope, which remains optically thick to NIR and processes the radiation to longer wavelengths. Based on their Karl G. Jansky Very Large Array (VLA) monitoring observations, Cesaroni et al. (2018) further reported exponential flux flaring in the radio continuum associated with SMA1 from 2016 July to 2017 February. This rising radio emission was interpreted as the radio jet breakout. Our 2017 July observation of both dust continuum and methanol maser subsequently indicates the dimming of this burst. Based on their monitoring data, Szymczak et al. (2018) also indicated the fast decline of 6.7 GHz CH_3OH maser brightness during 2016-2017, depending on the maser velocity component. These evidence hints toward a burst duration around two years.

What may be the origin of the luminosity burst in S255IR SMA1? Variable accretion is not uncommon in 3D numerical radiation hydrodynamic simulations of (low-mass and primordial) star formation (e.g., Vorobyov & Basu 2015; Hosokawa et al. 2016). Asymmetric features like spirals form in the circumstellar disk and lead to fluctuating accretion rates. Moreover, Meyer et al. (2017) suggested the universal sporadic and variable nature of gaseous material accreting from the circumstellar disks to massive YSOs as in their low-mass counterparts. In their investigations of the collapse of 100 $M_\odot$ pre-stellar cores, clumps of molecular gas spiraling from a few hundred au in the disk down to a few tens au from the central massive YSO and episodically accretes onto the star. The fact that S255IR SMA1 submillimeter continuum emission brightened up and dimmed down in conjunction with Class II methanol maser activities is suggestive of variation in the IR radiation field and supports the notion of a disk-mediated accretion-related event as suggested by Caratti o Garatti et al. (2017). Indeed, on the large (10,000 au) scale, several lines of evidence point to the presence of a rotating or flattened structure associated with S255IR SMA1 (Wang et al. 2011; Zinchenko et al. 2012, 2015; Boley et al. 2013)

For the low-mass star case, bursts of FUors and EXors are categorized with different characteristics. While FUor bursts typically arise with increases in mass accretion by several thousand folds and persist for years to decades, EXor bursts have enhanced mass accretion by factors of tens to hundreds and last for just months to years (Hartmann et al. 2016). Considering the relative mild magnitude and the short duration of the flare of S255IR SMA1, its temporal behavior resembles the milder and more frequent burst events, analog to those seen in the EXors for low-mass YSOs. That being said, in an absolute sense, the scale of energy released by massive YSO events like this one in S255IR SMA1 or the burst seen in NGC 6334(I) (Hunter et al. 2017) is dramatically different from the low-mass YSO cases. The luminosity of S255IR SMA1 at its burst stage, reaching 10^5 $L_\odot$, corresponds to a mass accretion rate of several times 10^{-3} $M_\odot$ (Caratti o Garatti et al. 2017). This is far more significant when compared with even the FUor bursts.

Monitoring observations of S255IR SMA1 in its continuum emission shall further constrain the full duration and degree of this latest burst. Meanwhile, supplementary molecular line observation could gauge the gas temperature, which may be subsequently warmed and cooled along the event. Readers are referred to Liu, S.-Y. et al., 2018, ApJ, 863, L12 for further details.

REFERENCES

- Audard, M., Ábrahám, P., Dunham, M. M., et al. 2014, in Protostars and Planets VI, ed. H. Beuther et al. (Tucson, AZ: Univ. Arizona Press), 387
- Boley, P. A., Linz, H., van Boekel, R., et al. 2013, A&A, 558, A24
- Caratti o Garatti, A., Stecklum, B., Garcia Lopez, R., et al. 2017, NatPh, 13, 276
- Cesaroni, R., Moscadelli, L., Neri, R., et al. 2018, arXiv:1802.04228
- Fujisawa, K., Yonekura, Y., Sugiyama, K., et al. 2015, ATel, 8286, 1
- Hartmann, L., Herczeg, G., & Calvet, N. 2016, ARA&A, 54, 135
- Hosokawa, T., Hirano, S., Kuiper, R., et al. 2016, ApJ, 824, 119
- Hunter, T. R., Brogan, C. L., MacLeod, G., et al. 2017, ApJL, 837, L29
- Hunter, T. R., Brogan, C. L., MacLeod, G. C., et al. 2018, ApJ, 854, 170
- Johnstone, D., Hendricks, B., Herczeg, G. J., & Bruderer, S. 2013, ApJ, 765, 133
- Jørgensen, J. K., Visser, R., Sakai, N., et al. 2013, ApJL, 779, L22
- Meyer, D. M.-A., Vorobyov, E. I., Kuiper, R., & Kley, W. 2017, MNRAS, 464, L90
- Moscadeli, L., Sanna, A., Goddi, C., et al., 2017, A&A, 600, L8
- Ojha, D. K., Samal, M. R., Pandey, A. K., et al. 2011, ApJ, 738, 156
- Safron, E. J., Fischer, W. J., Megeath, S. T., et al. 2015, ApJL, 800, L5
- Stecklum, B., Caratti o Garatti, A., Cardenas, M. C., et al. 2016, ATel, 8732, 1
- Szymczak, M., Olech, M., Wolak, P., et al. 2018, A&A, 617, A80
- Vorobyov, E. I., & Basu, S. 2015, ApJ, 805, 115
- Wang, Y., Beuther, H., Bik, A., et al. 2011, A&A, 527, A32
- Yoo, H., Lee, J.-E., Mairs, S., et al. 2017, ApJ, 849, 69
- Zinchenko, I., Liu, S.-Y., Su, Y.-N., et al. 2012, ApJ, 755, 177
- Zinchenko, I., Liu, S.-Y., Su, Y.-N., et al. 2015, ApJ, 810, 10
- Zinchenko, I., Liu, S.-Y., Su, Y.-N., & Sobolev, A. M. 2017, A&A, 606, L6

SMA DATA ARCHIVING AT THE RTDC

Holly Thomas (CfA)

With every new facility or upgrade, the size of astronomical datasets increases, and the SMA is no exception. Following the switch-over from the ASIC correlator to SWARM, the amount of data collected has increased by ~2600%. On good nights, the SMA now routinely generates around 200GB of data; and in 2017, the first year all four quadrants of SWARM were operational, over 20TB of data were taken. The job of storing and archiving this data is undertaken by the Radio Telescope Data Center (RTDC).

ABOUT THE RTDC

The RTDC is a group in the Radio and Geoastronomy division of the Center for Astrophysics that is responsible for archiving and distributing data from Smithsonian Astrophysical Observatory radio telescopes. We also supply the hardware and software necessary for our users to reduce and analyze these data.

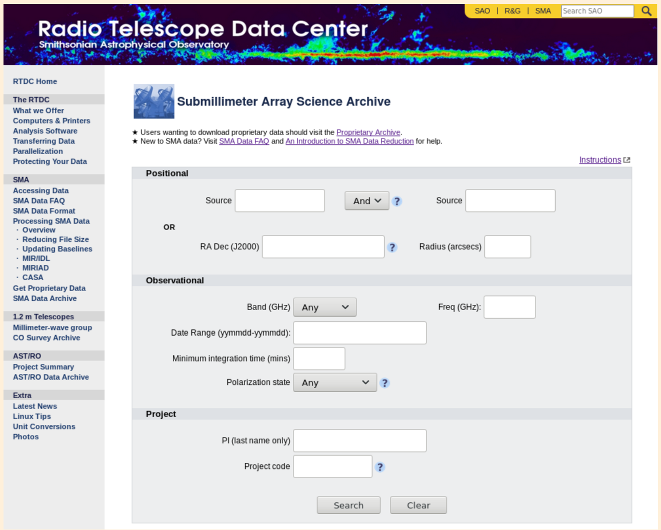
Each night SMA data is transferred from Hilo to the RTDC in Cambridge; from there it is served out to our CfA users on the RTDC network. Data files are listed in our online archives which are visible to users outside the CfA. The RTDC manages three web-based archives for the SMA: proprietary science data, non-proprietary data of all types, and calibration data only.

The RTDC website provides links to the archives along with web pages dedicated to the handling of SMA data. Here users can find information on data access, data format, and comprehensive data reduction information. As reducing SMA data can sometimes be daunting to the uninitiated, we provide an extensive FAQ page, clear recommendations, and illustrated step-by-step tutorials.

CURRENT AND FUTURE ARCHIVES

The last 18 months have seen a series of changes to the main (non-proprietary) SMA archive (see **Figure 1**). Seasoned users may notice a number of new features: the search criteria has been expanded to include the SMA project code, polarization state, and frequency (previous only the receiver band could be selected); users can now search multiple sets of coordinates; and the individual results now link to the relevant observing report.

A new proprietary data archive was introduced in 2017. This allows users to access their data securely and conveniently. The archive also allows PIs to request spectrally rebinned data in order to reduce the file size.



★ Users wanting to download proprietary data should visit the Proprietary Archive.
★ New to SMA data? Visit SMA Data FAQ and An Introduction to SMA Data Reduction for help.

Figure 1

With the current archives optimized, the next big challenge for the RTDC will be producing calibrated and imaged datasets. We anticipate that the first iteration of a pipeline will produce integrated images that can be used as thumbnails for the existing archives. Although not full science-quality they will serve to give users an idea of what to expect from the raw data they download. There is a long way to go before science-ready calibrated data is available, however, work is beginning and readers can stay informed via the RTDC webpage.

THE STORAGE CHALLENGE

Since the first chunk of the SWARM correlator came online in 2016, the size of datasets has ballooned. The SMA has gone from collecting less than 1TB of science data in 2014, to over 20TB in 2018. The size of the complete SMA archive now stands at 53TB. Two additional SWARM chunks are expected to be operational next semester, leading us to anticipate 30-35TB a year with ease. The projected increase in the size of the data is not solely due to the widening bandwidth: an increased demand for polarization tracks, in addition to the shorter scan times used for large mosaics, will both act to boost the file sizes. **Figure 2** shows a growth scenario for raw science data based on an additional two SWARM chunks for the 2019A semester, with two more chunks coming online in 2020. In this case, we can expect to be dealing with an archive of 190TB within 3 years.

How is the RTDC meeting this storage challenge? We recently purchased a dedicated SMA storage server with 160TB of disk space which will serve us for a couple more years. RTDC plans for future data storage are currently under discussion and review however it is increasingly likely that SMA storage, at least for non-proprietary data, will be in the cloud.

These days there are many cloud service providers to choose from and their benefits are certainly undeniable. Data stored in the cloud won't degrade, there are no concerns about disk failures, and the size can be expanded without downtime. Moving the public archive to the cloud would be a big step, and difficult to reverse; however, it is likely to prove the best option for securely and reliably keeping users supplied with even the largest datasets.

We encourage you to visit the RTDC website for information on SMA data processing and links to our archives. While we regularly post information on our homepage news feed, you can expect to find any major upgrades to the archive announced in future editions of this newsletter.

LINKS:

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

https://www.cfa.harvard.edu/cgi-bin/sma/smaarch.pl

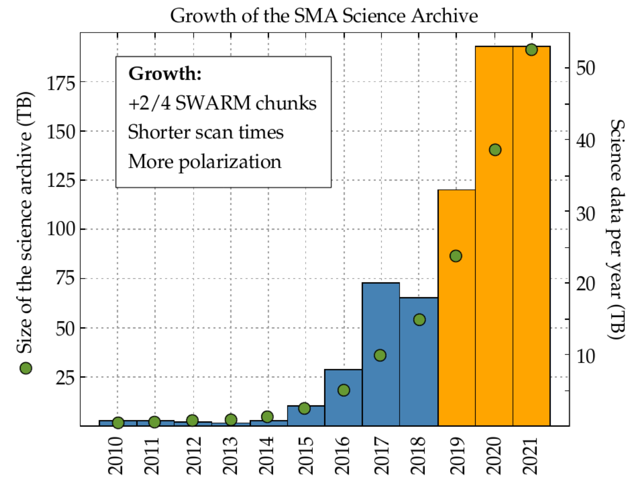


Figure 2

CALL FOR LARGE SCALE AND STANDARD PROJECTS PROPOSALS - 2019A SEMESTER

We wish to draw your attention to the Large Scale Projects program for observations with the Submillimeter Array (SMA), which is now accepting Notices of Intent to propose. Under this program, proposals dedicated to answering major astrophysical questions having significant scientific impact requiring observing times of order 100-1000 hours are solicited. In this communication, we are also pre-announcing the dates for standard observing proposals. These calls are for the 2019A semester with observing period May 16, 2019 – Nov 15, 2019.

The SMA is a reconfigurable interferometric array of eight 6-m antennas on Maunakea jointly built and operated by the Smithsonian Astrophysical Observatory and the Academia Sinica Institute of Astronomy and Astrophysics. The array operates in the 230, 345 and 400 GHz bands.

SMA has recently completed significant upgrades in observational capability, with more under way. 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 250 or 600 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 35 and 80 mJy. The small antennas allow access to low spatial frequencies in the sub-compact configuration, and at the other extreme, the finest angular resolution with the very extended configuration at 345 GHz is ~ 0.25". The compact and extended configurations complete the range. Thus, in some ways, the characteristics and performance of the SMA are 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 (http://sma1.sma.hawaii.edu/status.html) and explore the set of SMA proposing tools (http://sma1.sma.hawaii.edu/tools.html). Current and archived SMA Newsletters available online (https://www.cfa.harvard.edu/sma/Newsletters/) provide a sampling of the wide variety of science possible with the SMA.

The Large Scale Projects program follows a phased development, submission and review path, with the final selection of successful proposals synchronized with the TAC process for regular proposals. Accordingly, a Notice of Intent (http://sma1.sma.hawaii.edu/legacysubmit.html) is required ahead of full submission. The deadlines are:

STANDARD OBSERVING PROPOSALS

Submissions open: **07 February 2019 (on or before)**
Submissions close: **07 March 2019**

LARGE SCALE PROJECTS PROPOSALS

Notice of Intent (Required): **10 January 2019**
Full submission: **13 February (US) / 14 February(Taiwan) 2019**

A second announcement will be circulated when the standard proposal system opens for submissions. For more details visit the following websites:

General - http://sma1.sma.hawaii.edu/proposing.html
Large Scale Projects - http://sma1.sma.hawaii.edu/call_largescale.html
Notice of Intent - http://sma1.sma.hawaii.edu/legacysubmit.html

Questions or comments regarding the Call for Large Scale Proposals can be addressed to sma-largescale@cfa.harvard.edu and on standard proposals to sma-proposal@cfa.harvard.edu.

Mark Gurwell
Chair, SMA Time Allocation Committee

SMA STAFF UPDATES IN CAMBRIDGE

Garrett “Karto” Keating, previously an SMA Postdoctoral Fellow with scientific focus in intensity mapping and molecular gas in high redshift galaxies, and a keen interest in improving the SMA’s capabilities to better enable his science, joined the SMA on July 09 as Project Scientist. His duties will include leading the effort to better understand, evaluate, and control the SMA’s instrument status, and improving the SMA’s capabilities by providing the necessary link between the science and instrumentation teams based in Cambridge, Hilo, and Taipei as the wSMA developments proceed.

Christopher Moriarty joined the SMA on September 19 as Computer Engineer. Chris has a masters degree in Computer Engineering and has previously worked as a Senior Systems Software Engineer at the STScI, where he oversaw the Astronomer Proposal Tool for JWST, and contributed to HiCAT — a demonstration coronograph for the LUVOIR mission. At the SMA, Chris will use his relevant expertise and experience to help modernize the SMA's software architecture, and its online and offline tools. He will also develop software to support the continually expanding capabilities of the SMA, such as the wSMA upgrade or the next-generation SWARM correlator development.

SMA STAFF UPDATES IN HILO

Andrew Weis, Astrophysicist (Telescope Operator), left the SMA in July to attend graduate school. We thank Andrew for his efforts and wish him success in the future.

Miriam Fuchs, Astrophysicist (Telescope Operator), left the SMA in August to work at the JCMT on Maunakea. We thank Miriam for her efforts and wish her success in the future.

Rob Christensen, Electronics Engineer, returned to SAO in August, reporting to Simon Radford. Recently Rob worked at the WIYN on Kitt Peak. Previously he worked for many years at the SMA on Maunakea. Rob will oversee receiver activities, provide essential support to maintaining the SMA’s operational readiness, and participate in the planning, design, and implementation of the wSMA.

Johnathan Larson, Astrophysicist (Telescope Operator), joined SAO in August, reporting to Ryan Howie. He recently completed his bachelor’s degree in physics at Cameron University after service in the US Army.

Kristen Laguaña, Astrophysicist (Telescope Operator), joined SAO in December, reporting to Ryan Howie. An astronomy and physics graduate of the University of Hawai‘i at Hilo, she previously worked at the YTLA on Maunaloa.

PROPOSAL STATISTICS 2018B (16 NOV 2018 - 15 MAY 2019)

The SMA received a total of 79 proposals (SAO 59) requesting observing time in the 2018B 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	24
local galaxies, starbursts, AGN	16
low/intermediate mass star formation, cores	10
submm/hi-z galaxies	8
evolved stars, AGB, PPN	5
GRB, SN, high energy	5
protoplanetary, transition, debris disks	4
UH	3
solar system	2
Galactic center	1
Other	1

TRACK ALLOCATIONS BY WEATHER REQUIREMENT (ALL PARTNERS):

PWV[1]	SAO	ASIAA	UH[2]
< 4.0mm	7A + 56B	3A + 13B	0
< 2.5mm	27A + 30B	6A + 6B	8
< 1.0mm	0A + 0B	3A + 0B	2
Total	**34A + 86B**	**12A + 19B**	**10**

(1) Precipitable water vapor required for the observations.

(2) UH does not list As and Bs.

TOP-RANKED SAO AND ASIAA PROPOSALS – 2018B 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.

GALACTIC CENTER

Michael Johnson, SAO
Polarimetric VLBI with the Event Horizon Telescope

GRB, SN, HIGH ENERGY

Kuiyun Huang, CYCU
New Insights in Short GRBs

HIGH MASS (OB) STAR FORMATION, CORES

Sheng-Yuan Liu, ASIAA
The Excitation and Variation of A Newly Discovered Methanol Maser in the Massive YSO S255~IR (copied from 2017B-A017)

Sheng-Yuan Liu, ASIAA
The Interplay between Magnetic Fields and Stellar Feedback in the Sequential Massive Star Forming Complex G9.62+0.19

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

LOCAL GALAXIES, STARBURSTS, AGN

Maria Jesus Jimenez-Donaire, Harvard-Smithsonian Center for Astrophysics
Searching for Embedded Super Star Clusters in M82

LOW/INTERMEDIATE MASS STAR FORMATION, CORES

Anaelle Maury, CEA, Paris Saclay University, Astrophysics department
Evidence of magnetic braking in Class 0 protostars : towards a statistical view

Hau-Yu Baobab Liu, ESO-Garching
Millimeter Flux Variability/Stability of FU Orionis Objects and EXors

Sigurd Jensen, Niels Bohr Institute, University of Copenhagen
Quantifying water deuteration toward the densely clustered Serpens SMM1 source.

PROTOPLANETARY, TRANSITION, DEBRIS DISKS

Jane Huang, Harvard-Smithsonian Center for Astrophysics
A pilot wideband chemical survey of Class I protostellar disks

Luca Matrà, Harvard-Smithsonian Center for Astrophysics
REsolved ALMA and SMA Observations of Nearby Stars (REASONS): a legacy population study of the formation location of planetesimal belts (part 3)

SOLAR SYSTEM

Charlie Qi, CfA
Close-up Imaging of Comet 46P/Wirtanen

SUBMM/HI-Z GALAXIES

Wei-Hao Wang, ASIAA
SMA Pilot STUDIES: Imaging the Brightest SCUBA-2 450 micron Sources

ALL SAO PROPOSALS – 2018A SEMESTER

The following is the listing of all SAO proposals observed in the 2018A semester (16 May 2018 – 15 Nov 2018)

Elizabeth Artur de la Villarmois, Niels Bohr Institut
Revealing star formation via sulphur chemistry

Yusuke Aso, ASIAA
Pilot Survey of Deuterated Molecules in Class 0 Protostars

Lennox Cowie, University of Hawaii
SMA followup of a unique lensed X-ray/radio source

Yan Gong, MPIfR
A SMA line survey toward an Orion-KL analog

Anna Ho, Caltech
SMA Monitoring of the Rare Relativistic Supernova AT2018cow

Anna Ho, Caltech
Rapidly Rising Blue Transient Discovered by ZTF

Peter Hofner, New Mexico Tech
The Outflow from the High-Mass Protostar ISOSS J23053+5953 SMM2

Sihan Jiao, Chinese Academy of Sciences
Continuation of SMA Public Survey towards the Orion Molecular Cloud

Maria Jesus Jimenez Donaire, CfA
Dense gas excitation and the universality of the star-formation efficiency in dense molecular gas

Tomasz Kaminski, CfA
Chemical and isotopic composition of the stellar-merger remnant, CK Vul

Erin Kara, University of Maryland
Testing the radio-jet / X-ray corona connection in a unique Gamma-ray Loud Seyfert

Alain Khayat, NASA and the University of Maryland
Characterizing the physical state of the Martian atmosphere during a global dust storm

Chia-Lin Ko, National Tsing Hua University
Abundance ratios of S-bearing molecules as an alternative probe of grain growth

Li-Wen Liao, National Tsing Hua University
Resolving and searching high-velocity jets in high-mass star-forming region

Hau-Yu Baobab Liu, ESO (Garching)
Millimeter Flux Variability/Stability of FU Orionis Objects and EXors

Luca Matrà, CfA
REsolved ALMA and SMA Observations of Nearby Stars (REASONS): a legacy population study of the formation location of planetesimal belts (part 2)

Anaelle Maury, CEA, Paris Saclay University
Evidence of magnetic braking in Class 0 protostars : towards a statistical view

Brett McGuire, NRAO
Moving Beyond Small Number Statistics - A SWARM Survey of Astrochemical Inventories

Tomoharu Oka, Faculty of Science and Technology
*Search for Intraday Flux Variation of the Intermediate-mass Black Hole Candidate CO-0.40-0.22**

Giulia Perotti, University of Copenhagen
Combined methanol ice-gas maps: the bridge between ice and gas

Shaye Storm, CfA
Forming the NGC 6334 Filament: Shocked Gas and Searching for Outflows

Alexandra Tetarenko, East Asian Observatory
Constraining Jet Formation and Evolution with Transient X-ray Binaries

Yuji Urata, National Central University
Search for Bright submm GRB afterglows Toward Radio Polarimetry

Jonathan Williams, University of Hawaii
Resolved observations of nearby stellar disks

Jonathan Williams, University of Hawaii
A search for cold debris

RECENT PUBLICATIONS

Title: Tracking the variable jets of V404 Cygni during its 2015 outburst
Authors: Tetarenko, A. J.; Sivakoff, G. R.; Miller-Jones, J. C. A.; Bremer, M.; Mooley, K. P.; Fender, R. P.; Rumsey, C.; Bahramian, A.; Altamirano, D.; Heinz, S.; Maitra, D.; Markoff, S. B.; Migliari, S.; Rupen, M. P.; Russell, D. M.; Russell, T. D.; Sarazin, C. L.
Publication: *Monthly Notices of the Royal Astronomical Society, Volume 482, Issue 3, p.2950-2972 (MNRAS Homepage)*
Publication Date: 01/2019
Abstract: http://adsabs.harvard.edu/abs/2019MNRAS.482.2950T

Title: Imaging the disc rim and a moving close-in companion candidate in the pre-transitional disc of V1247 Orionis
Authors: Willson, Matthew; Kraus, Stefan; Kluska, Jacques; Monnier, John D.; Cure, Michel; Sitko, Mike; Aarnio, Alicia; Ireland, Michael J.; Rizzuto, Aaron; Hone, Edward; Kreplin, Alexander; Andrews, Sean; Calvet, Nuria; Espaillat, Catherine; Fukagawa, Misato; Harries, Tim J.; Hinkley, Sasha; Kanaan, Samer; Muto, Takayuki; Wilner, David J.
Publication: *Astronomy & Astrophysics, Volume 621, id.A7, 17 pp. (A&A Homepage)*
Publication Date: 12/2018
Abstract: http://adsabs.harvard.edu/abs/2018A&A...621A...7W

Title: The luminous host galaxy, faint supernova and rapid afterglow rebrightening of GRB 100418A
Authors: de Ugarte Postigo, A.; Thöne, C. C.; Bensch, K.; van der Horst, A. J.; Kann, D. A.; Cano, Z.; Izzo, L.; Goldoni, P.; Martín, S.; Filgas, R.; Schady, P.; Gorosabel, J.; Bikmaev, I.; Bremer, M.; Burenin, R.; Castro-Tirado, A. J.; Covino, S.; Fynbo, J. P. U.; Garcia-Appadoo, D.; de Gregorio-Monsalvo, I.; Jelínek, M.; Khamitov, I.; Kamble, A.; Kouveliotou, C.; Krühler, T.; Leloudas, G.; Melnikov, S.; Nardini, M.; Perley, D. A.; Petitpas, G.; Pooley, G.; Rau, A.; Rol, E.; Sánchez-Ramírez, R.; Starling, R. L. C.; Tanvir, N. R.; Wiersema, K.; Wijers, R. A. M. J.; Zafar, T.
Publication: *Astronomy & Astrophysics, Volume 620, id.A190, 23 pp. (A&A Homepage)*
Publication Date: 12/2018
Abstract: http://adsabs.harvard.edu/abs/2018A&A...620A.190D

Title: A 1000 AU Scale Molecular Outflow Driven by a Protostar with an age of <4000 Years
Authors: Furuya, Ray S.; Kitamura, Yoshimi; Shinnaga, Hiroko
Publication: *eprint arXiv:1812.07806*
Publication Date: 12/2018
Abstract: http://adsabs.harvard.edu/abs/2018arXiv181207806F

Title: CO multi-line observations of HH 80-81: a two-component molecular outflow associated with the largest protostellar jet in our Galaxy
Authors: Qiu, Keping; Wyrowski, Friedrich; Menten, Karl; Zhang, Qizhou; Guesten, Rolf
Publication: *eprint arXiv:1812.03501*
Publication Date: 12/2018
Abstract: http://adsabs.harvard.edu/abs/2018arXiv181203501Q

Title: Extreme fragmentation and complex kinematics at the center of the L1287 cloud
Authors: Juárez, Carmen; Liu, Hauyu-Baobab; Girart, Josep M.; Palau, Aina; Busquet, Gemma; Galván-Madrid, Roberto; Hirano, Naomi; Lin, Yuxin
Publication: *eprint arXiv:1811.08517*
Publication Date: 11/2018
Abstract: http://adsabs.harvard.edu/abs/2018arXiv181108517J

Title: SMA line observations of the CH$_3$OH-maser outflow in DR21(OH)
Authors: Orozco-Aguilera, Ma. T.; Hernández-Gómez, Antonio; Zapata, Luis A.
Publication: *eprint arXiv:1811.01880*
Publication Date: 11/2018
Abstract: http://adsabs.harvard.edu/abs/2018arXiv181101880O

Title: Planck's dusty GEMS. V. Molecular wind and clump stability in a strongly lensed star-forming galaxy at z = 2.2
Authors: Cañameras, R.; Nesvadba, N. P. H.; Limousin, M.; Dole, H.; Kneissl, R.; Koenig, S.; Le Floc'h, E.; Petitpas, G.; Scott, D.
Publication: *Astronomy & Astrophysics, Volume 620, id.A60, 23 pp. (A&A Homepage)*
Publication Date: 11/2018
Abstract: http://adsabs.harvard.edu/abs/2018A&A...620A..60C

Title: Multi-wavelength characterization of the blazar S5 0716+714 during an unprecedented outburst phase
Authors: MAGIC Collaboration; Ahnen, M. L.; Ansoldi, S.; Antonelli, L. A.; Arcaro, C.; Baack, D.; Babić, A.; Banerjee, B.; Bangale, P.; Barres de Almeida, U.; Barrio, J. A.; Becerra González, J.; Bednarek, W.; Bernardini, E.; Ch Berse, R.; Berti, A.; Bhattacharyya, W.; Biland, A.; Blanch, O.; Bonnoli, G.; Carosi, R.; Carosi, A.; Ceribella, G.; Chatterjee, A.; Colak, S. M.; Colin, P.; Colombo, E.; Contreras, J. L.; Cortina, J.; Covino, S.; Cumani, P.; da Vela, P.; Dazzi, F.; de Angelis, A.; de Lotto, B.; Delfino, M.; Delgado, J.; di Pierro, F.; Domínguez, A.; Dominis Prester, D.; Dorner, D.; Doro, M.; Einecke, S.; Elsaesser, D.; Fallah Ramazani, V.; Fernández-Barral, A.; Fidalgo, D.; Fonseca, M. V.; Font, L.; Fruck, C.; Galindo, D.; Gallozzi, S.; García López, R. J.; Garczarczyk, M.; Gaug, M.; Giammaria, P.; Godinović, N.; Gora, D.; Guberman, D.; Hadasch, D.; Hahn, A.; Hassan, T.; Hayashida, M.; Herrera, J.; Hose, J.; Hrupec, D.; Ishio, K.; Konno, Y.; Kubo, H.; Kushida, J.; Kuveždić, D.; Lelas, D.; Lindfors, E.; Lombardi, S.; Longo, F.; López, M.; Maggio, C.; Majumdar, P.; Makariev, M.; Maneva, G.; Manganaro, M.; Mannheim, K.; Maraschi, L.; Mariotti, M.; Martínez, M.; Masuda, S.; Mazin, D.; Mielke, K.; Minev, M.; Miranda, J. M.; Mirzoyan, R.; Moralejo, A.; Moreno, V.; Moretti, E.; Nagayoshi, T.; Neustroev, V.; Niedzwiecki, A.; Nievas Rosillo, M.; Nigro, C.; Nilsson, K.; Ninci, D.; Nishijima, K.; Noda, K.; Nogués, L.; Paiano, S.; Palacio, J.; Paneque, D.; Paoletti, R.; Paredes, J. M.; Pedaletti, G.; Peresano, M.; Persic, M.; Prada Moroni, P. G.; Prandini, E.; Puljak, I.; Garcia, J. R.; Reichardt, I.; Rhode, W.; Ribó, M.; Rico, J.; Righi, C.; Rugliancich, A.; Saito, T.; Satalecka, K.; Schweizer, T.; Sitarek, J.; Šnidarić, I.; Sobczynska, D.; Stamerra, A.; Strzys, M.; Surić, T.; Takahashi, M.; Takalo, L.; Tavecchio, F.; Temnikov, P.; Terzić, T.; Teshima, M.; Torres-Albà, N.; Treves, A.; Tsujimoto, S.; Vanzo, G.; Vazquez Acosta, M.; Vovk, I.; Ward, J. E.; Will, M.; Zarić, D.; Fermi-Lat Collaboration; Bastieri, D.; Gasparrini, D.; Lott, B.; Rani, B.; Thompson, D. J.; MWL Collaborators; Agudo, I.; Angelakis, E.; Borman, G. A.; Casadio, C.; Grishina, T. S.; Gurwell, M.; Hovatta, T.; Itoh, R.; Järvelä, E.; Jermak, H.; Jorstad, S.; Kopatskaya, E. N.; Kraus, A.; Krichbaum, T. P.; Kuin, N. P. M.; Lähteenmäki, A.; Larionov, V. M.; Larionova, L. V.; Lien, A. Y.; Madejski, G.; Marscher, A.; Myserlis, I.; Max-Moerbeck, W.; Molina, S. N.; Morozova, D. A.; Nalewajko, K.; Pearson, T. J.; Ramakrishnan, V.; Readhead, A. C. S.; Reeves, R. A.; Savchenko, S. S.; Steele, I. A.; Tornikoski, M.; Troitskaya, Yu. V.; Troitsky, I.; Vasilyev, A. A.; Zensus, J. Anton
Publication: *Astronomy & Astrophysics, Volume 619, id.A45, 18 pp. (A&A Homepage)*
Publication Date: 11/2018
Abstract: http://adsabs.harvard.edu/abs/2018A&A...619A..45M

Title: Non-Zeeman circular polarization of molecular spectral lines in the ISM
Authors: Chamma, Mohammed Afif; Houde, Martin; Girart, Josep Miquel; Rao, Ramprasad
Publication: *Monthly Notices of the Royal Astronomical Society, Volume 480, Issue 3, p.3123-3131 (MNRAS Homepage)*
Publication Date: 11/2018
Abstract: http://adsabs.harvard.edu/abs/2018MNRAS.480.3123C

Title: Physical and Chemical Conditions of the Protostellar Envelope and the Protoplanetary Disk in HL Tau
Authors: Wu, Chun-Ju; Hirano, Naomi; Takakuwa, Shigehisa; Yen, Hsi-Wei; Aso, Yusuke
Publication: *eprint arXiv:1810.13081*
Publication Date: 10/2018
Abstract: http://adsabs.harvard.edu/abs/2018arXiv181013081W

Title: Revealing the Broad Line Region of NGC 1275: The Relationship to Jet Power
Authors: Punsly, Brian; Marziani, Paola; Bennert, Vardha N.; Nagai, Hiroshi; Gurwell, Mark A.
Publication: *eprint arXiv:1810.11716*
Publication Date: 10/2018
Abstract: http://adsabs.harvard.edu/abs/2018arXiv181011716P

Title: AT2018cow: a luminous millimeter transient
Authors: Ho, Anna Y. Q.; Phinney, E. Sterl; Ravi, Vikram; Kulkarni, S. R.; Petitpas, Glen; Emonts, Bjorn; Bhalerao, Varun; Blundell, Ray; Cenko, S. Bradley; Dobie, Dougal; Howie, Ryan; Kamraj, Nikita; Kasliwal, Mansi M.; Murphy, Tara; Perley, Daniel A.; Sridharan, T. K.; Yoon, Ilsang
Publication: *eprint arXiv:1810.10880*
Publication Date: 10/2018
Abstract: http://adsabs.harvard.edu/abs/2018arXiv181010880H

Title: The physical and chemical properties of the ρ ophiuchi A dense core
Authors: Chen, Yu-Ching; Hirano, Naomi
Publication: *eprint arXiv:1810.08226*
Publication Date: 10/2018
Abstract: http://adsabs.harvard.edu/abs/2018arXiv181008226C

Title: Gas infall in the massive star formation core G192.16-3.84
Authors: Tang, Mengyao; Qin, Sheng-Li; Liu, Tie; Wu, Yuefang
Publication: *eprint arXiv:1810.01597*
Publication Date: 10/2018
Abstract: http://adsabs.harvard.edu/abs/2018arXiv181001597T

Title: Extremely Dense Cores Associated with Chandra Sources in Ophiuchus A: Forming Brown Dwarfs Unveiled?
Authors: Kawabe, Ryohei; Hara, Chihomi; Nakamura, Fumitaka; Saigo, Kazuya; Kamazaki, Takeshi; Shimajiri, Yoshito; Tomida, Kengo; Takakuwa, Shigehisa; Tsuboi, Yohko; Machida, Masahiro N.; Di Francesco, James; Friesen, Rachel; Hirano, Naomi; Oasa, Yumiko; Tamura, Motohide; Tamura, Yoichi; Tsukagoshi, Takashi; Wilner, David
Publication: *The Astrophysical Journal, Volume 866, Issue 2, article id. 141, 15 pp. (2018). (ApJ Homepage)*
Publication Date: 10/2018
Abstract: http://adsabs.harvard.edu/abs/2018ApJ...866..141K

Title: Molecular Gas and Star Formation Properties in Early Stage Mergers: SMA CO(2-1) Observations of the LIRGs NGC 3110 and NGC 232
Authors: Espada, Daniel; Martin, Sergio; Verley, Simon; Pettitt, Alex R.; Matsushita, Satoki; Argudo-Fernández, Maria; Randriamanakoto, Zara; Hsieh, Pei-Ying; Saito, Toshiki; Miura, Rie E.; Kawana, Yuka; Sabater, Jose; Verdes-Montenegro, Lourdes; Ho, Paul T. P.; Kawabe, Ryohei; Iono, Daisuke
Publication: *The Astrophysical Journal, Volume 866, Issue 2, article id. 77, 21 pp. (2018). (ApJ Homepage)*
Publication Date: 10/2018
Abstract: http://adsabs.harvard.edu/abs/2018ApJ...866...77E

Title: Scaling Relations Associated with Millimeter Continuum Sizes in Protoplanetary Disks
Authors: Andrews, Sean M.; Terrell, Marie; Tripathi, Anjali; Ansdell, Megan; Williams, Jonathan P.; Wilner, David J.
Publication: *The Astrophysical Journal, Volume 865, Issue 2, article id. 157, 26 pp. (2018). (ApJ Homepage)*
Publication Date: 10/2018
Abstract: http://adsabs.harvard.edu/abs/2018arXiv180810510A

Title: Interactions Between Gas Dynamics and Magnetic Fields in the Massive Dense Cores of the DR21 Filament
Authors: Ching, Tao-Chung; Lai, Shih-Ping; Zhang, Qizhou; Girart, Josep M.; Qiu, Keping; Liu, Hauyu B.
Publication: *The Astrophysical Journal, Volume 865, Issue 2, article id. 110, 17 pp. (2018). (ApJ Homepage)*
Publication Date: 10/2018
Abstract: http://adsabs.harvard.edu/abs/2018arXiv180803459C

Title: Two sub-millimetre bright protoclusters bounding the epoch of peak star formation activity
Authors: Lacaille, Kevin; Chapman, Scott; Smail, Ian; Steidel, Charles; Blain, Andrew; Geach, James; Golob, Anneya; Gurwell, Mark; Ivison, Rob; Reddy, Naveen; Sawicki, Marcin
Publication: *eprint arXiv:1809.06882*
Publication Date: 09/2018
Abstract: http://adsabs.harvard.edu/abs/2018arXiv180906882L

Title: Submillimeter Array Observations of Extended CO (J = 2 - 1) Emission in the Interacting Galaxy NGC 3627
Authors: Law, Charles J.; Zhang, Qizhou; Ricci, Luca; Petitpas, Glen; Jiménez-Donaire, Maria J.; Ueda, Junko; Lu, Xing; Dunham, Michael M.
Publication: *The Astrophysical Journal, Volume 865, Issue 1, article id. 17, 13 pp. (2018). (ApJ Homepage)*
Publication Date: 09/2018
Abstract: http://adsabs.harvard.edu/abs/2018arXiv180807483L

Title: Possible Counterrotation between the Disk and Protostellar Envelope around the Class I Protostar IRAS 04169+2702
Authors: Takakuwa, Shigehisa; Tsukamoto, Yusuke; Saigo, Kazuya; Saito, Masao
Publication: *The Astrophysical Journal, Volume 865, Issue 1, article id. 51, 17 pp. (2018). (ApJ Homepage)*
Publication Date: 09/2018
Abstract: http://adsabs.harvard.edu/abs/2018arXiv180806039T

Title: Multiwavelength photometric and spectropolarimetric analysis of the FSRQ 3C 279
Authors: Patiño-Álvarez, V. M.; Fernandes, S.; Chavushyan, V.; López-Rodríguez, E.; León-Tavares, J.; Schlegel, E. M.; Carrasco, L.; Valdés, J.; Carramiñana, A.
Publication: *Monthly Notices of the Royal Astronomical Society, Volume 479, Issue 2, p.2037-2064 (MNRAS Homepage)*
Publication Date: 09/2018
Abstract: http://adsabs.harvard.edu/abs/2018MNRAS.479.2037P

Title: H2CO Ortho-to-para Ratio in the Protoplanetary Disk HD 163296
Authors: Guzmán, V. V.; Öberg, K. I.; Carpenter, J.; Le Gal, R.; Qi, C.; Pagues, J.
Publication: *The Astrophysical Journal, Volume 864, Issue 2, article id. 170, 9 pp. (2018). (ApJ Homepage)*
Publication Date: 09/2018
Abstract: http://adsabs.harvard.edu/abs/2018ApJ...864..170G

Title: Multiwavelength Light Curves of Two Remarkable Sagittarius A* Flares
Authors: Fazio, G. G.; Hora, J. L.; Witzel, G.; Willner, S. P.; Ashby, M. L. N.; Baganoff, F.; Becklin, E.; Carey, S.; Haggard, D.; Gammie, C.; Ghez, A.; Gurwell, M. A.; Ingalls, J.; Marrone, D.; Morris, M. R.; Smith, H. A.
Publication: *The Astrophysical Journal, Volume 864, Issue 1, article id. 58, 7 pp. (2018). (ApJ Homepage)*
Publication Date: 09/2018
Abstract: http://adsabs.harvard.edu/abs/2018ApJ...864...58F

Title: A Submillimeter Burst of S255IR SMA1: The Rise and Fall of Its Luminosity
Authors: Liu, Sheng-Yuan; Su, Yu-Nung; Zinchenko, Igor; Wang, Kuo-Song; Wang, Yuan
Publication: *The Astrophysical Journal Letters, Volume 863, Issue 1, article id. L12, 6 pp. (2018). (ApJL Homepage)*
Publication Date: 08/2018
Abstract: http://adsabs.harvard.edu/abs/2018ApJ...863L..12L

Title: Mass Assembly of Stellar Systems and Their Evolution with the SMA (MASSES) - 1.3 mm Subcompact Data Release
Authors: Stephens, Ian W.; Dunham, Michael M.; Myers, Philip C.; Pokhrel, Riwaj; Bourke, Tyler L.; Vorobyov, Eduard I.; Tobin, John J.; Sadavoy, Sarah I.; Pineda, Jaime E.; Offner, Stella S. R.; Lee, Katherine I.; Kristensen, Lars E.; Jørgensen, Jes K.; Goodman, Alyssa A.; Arce, Héctor G.; Gurwell, Mark
Publication: *The Astrophysical Journal Supplement Series, Volume 237, Issue 2, article id. 22, 21 pp. (2018). (ApJS Homepage)*
Publication Date: 08/2018
Abstract: http://adsabs.harvard.edu/abs/2018arXiv180607397S

Title: Astronomical detection of radioactive molecule 26AlF in the remnant of an ancient explosion
Authors: Kamiński, Tomasz; Tylenda, Romuald; Menten, Karl M.; Karakas, Amanda; Winters, Jan Martin; Breier, Alexander A.; Wong, Ka Tat; Giesen, Thomas F.; Patel, Nimesh A.
Publication: *Nature Astronomy, Volume 2, p. 778-783*
Publication Date: 07/2018
Abstract: http://adsabs.harvard.edu/abs/2018NatAs...2..778K/

Title: Exploring the Variability of the Flat-spectrum Radio Source 1633+382. II. Physical Properties
Authors: Algaba, Juan-Carlos; Lee, Sang-Sung; Rani, Bindu; Kim, Dae-Won; Kino, Motoki; Hodgson, Jeffrey; Zhao, Guang-Yao; Byun, Do-Young; Gurwell, Mark; Kang, Sin-Cheol; Kim, Jae-Young; Kim, Jeong-Sook; Kim, Soon-Wook; Park, Jong-Ho; Trippe, Sascha; Wajima, Kiyoaki
Publication: *The Astrophysical Journal, Volume 859, Issue 2, article id. 128, 12 pp. (2018). (ApJ Homepage)*
Publication Date: 06/2018
Abstract: http://adsabs.harvard.edu/abs/2018ApJ...859..128A

Title: A Search for Molecular Gas in the Host Galaxy of FRB 121102
Authors: Bower, Geoffrey C.; Rao, Ramprasad; Krips, Melanie; Maddox, Natasha; Bassa, Cees; Adams, Elizabeth A. K.; Law, C. J.; Tendulkar, Shriharsh P.; van Langevelde, Huib Jan; Paragi, Zsolt; Butler, Bryan J.; Chatterjee, Shami
Publication: *The Astronomical Journal, Volume 155, Issue 6, article id. 227, 5 pp. (2018). (AJ Homepage)*
Publication Date: 06/2018
Abstract: http://adsabs.harvard.edu/abs/2018AJ....155..227B

Title: Red, redder, reddest: SCUBA-2 imaging of colour-selected Herschel sources
Authors: Duivenvoorden, S.; Oliver, S.; Scudder, J. M.; Greenslade, J.; Riechers, D. A.; Wilkins, S. M.; Buat, V.; Chapman, S. C.; Clements, D. L.; Cooray, A.; Coppin, K. E. K.; Dannerbauer, H.; De Zotti, G.; Dunlop, J. S.; Eales, S. A.; Efstathiou, A.; Farrah, D.; Geach, J. E.; Holland, W. S.; Hurley, P. D.; Ivison, R. J.; Marchetti, L.; Petitpas, G.; Sargent, M. T.; Scott, D.; Symeonidis, M.; Vaccari, M.; Vieira, J. D.; Wang, L.; Wardlow, J.; Zemcov, M.
Publication: *Monthly Notices of the Royal Astronomical Society, Volume 477, Issue 1, p.1099-1119 (MNRAS Homepage)*
Publication Date: 06/2018
Abstract: http://adsabs.harvard.edu/abs/2018MNRAS.477.1099D

Title: Filamentary Fragmentation and Accretion in High-mass Star-forming Molecular Clouds
Authors: Lu, Xing; Zhang, Qizhou; Liu, Hauyu Baobab; Sanhueza, Patricio; Tatematsu, Ken'ichi; Feng, Siyi; Smith, Howard A.; Myers, Philip C.; Sridharan, T. K.; Gu, Qiusheng
Publication: *The Astrophysical Journal, Volume 855, Issue 1, article id. 9, 30 pp. (2018). (ApJ Homepage)*
Publication Date: 03/2018
Abstract: http://adsabs.harvard.edu/abs/2018ApJ...855....9L

Title: KVN observations reveal multiple γ-ray emission regions in 3C 84?
Authors: Hodgson, Jeffrey A.; Rani, Bindu; Lee, Sang-Sung; Algaba, Juan Carlos; Kino, Motoki; Trippe, Sascha; Park, Jong-Ho; Zhao, Guang-Yao; Byun, Do-Young; Kang, Sincheol; Kim, Jae-Young; Kim, Jeong-Sook; Kim, Soon-Wook; Miyazaki, Atsushi; Wajima, Kiyoaki; Oh, Junghwan; Kim, Dae-won; Gurwell, Mark
Publication: *Monthly Notices of the Royal Astronomical Society, Volume 475, Issue 1, p.368-378 (MNRAS Homepage)*
Publication Date: 03/2018
Abstract: http://adsabs.harvard.edu/abs/2018MNRAS.475..368H

Title: Revisiting the Extended Schmidt Law: The Important Role of Existing Stars in Regulating Star Formation
Authors: Shi, Yong; Yan, Lin; Armus, Lee; Gu, Qiusheng; Helou, George; Qiu, Keping; Gwyn, Stephen; Stierwalt, Sabrina; Fang, Min; Chen, Yanmei; Zhou, Luwenjia; Wu, Jingwen; Zheng, Xianzhong; Zhang, Zhi-Yu; Gao, Yu; Wang, Junzhi
Publication: *The Astrophysical Journal, Volume 853, Issue 2, article id. 149, 9 pp. (2018). (ApJ Homepage)*
Publication Date: 02/2018
Abstract: http://adsabs.harvard.edu/abs/2018ApJ...853..149S

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.

SUBMILLIMETER ARRAY
Harvard-Smithsonian Center
for Astrophysics
60 Garden Street, MS 78
Cambridge, MA 02138 USA
www.cfa.harvard.edu/sma/

SMA HILO OFFICE
645 North A'ohoku Place
Hilo, Hawaii 96720
Ph. 808.961.2920
Fx. 808.961.2921
sma1.sma.hawaii.edu

ACADEMIA SINICA INSTITUTE OF ASTRONOMY & ASTROPHYSICS
P.O. Box 23-141
Taipei 10617
Taiwan R.O.C.
www.asiaa.sinica.edu.tw/