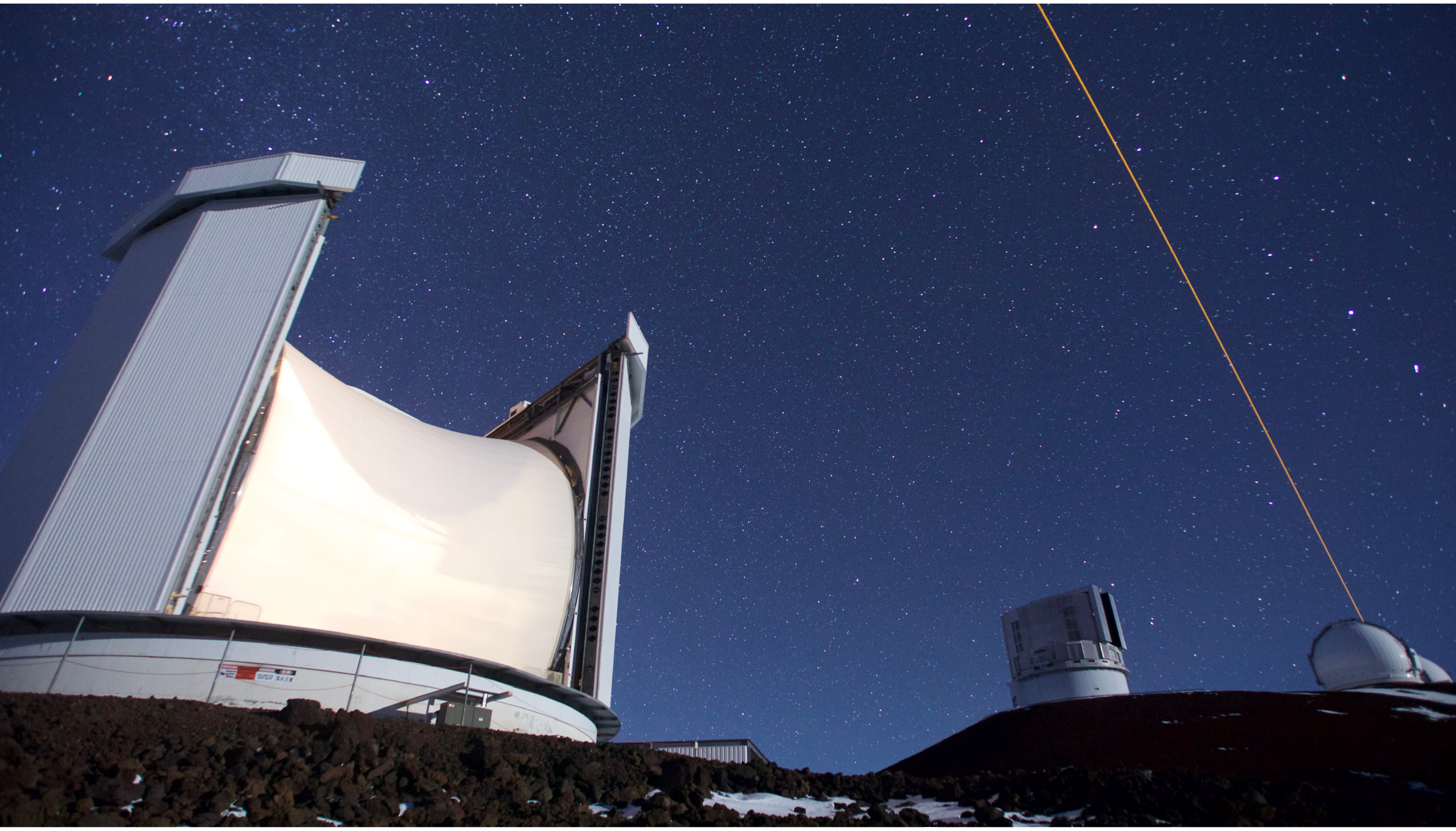
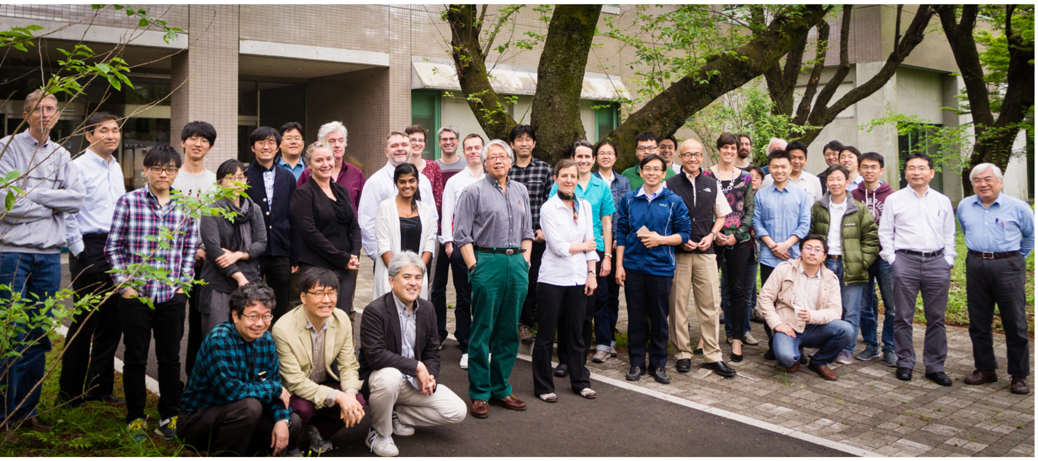
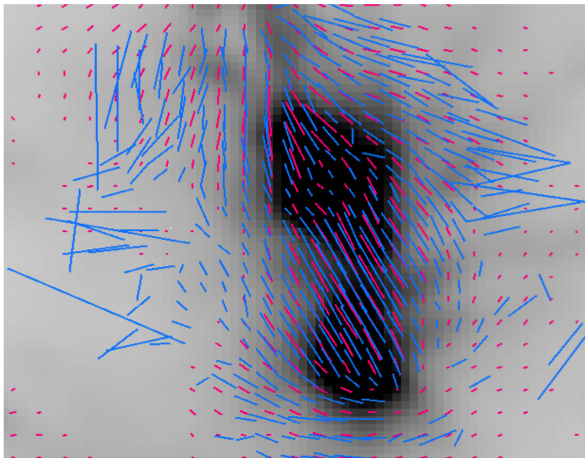
James Clerk Maxwell Telescope
East Asian Observatory

# East Asian Observatory News







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**In this Issue:**




East Asian Observatory

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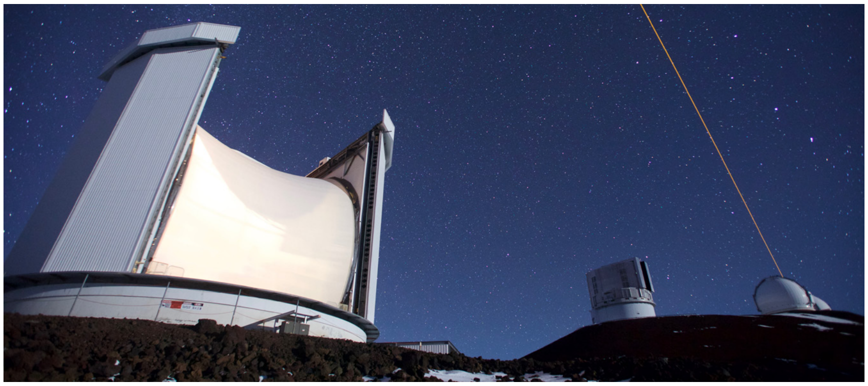
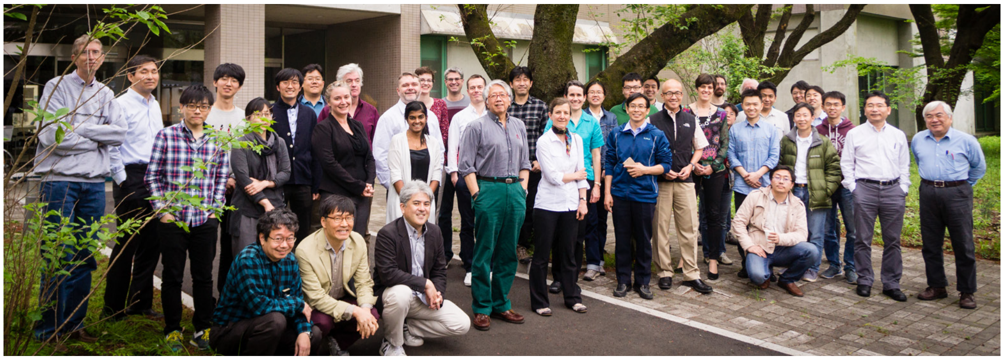
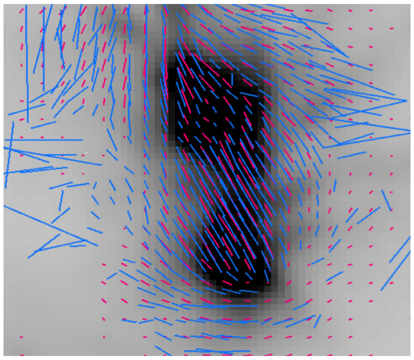


From the front cover. Top: JCMT observing at night with the Subaru and Keck telescopes visible on the summit ridge behind (credit: William Montgomerie). Bottom Left: Participants and EAO staff at the first JCMT Users meeting in Mitaka, Japan, April 2016. Bottom Right: POL-2 measurements towards the Orion region (credit: Kate Pattle and the POL-2 commissioning team/BISTRO consortium).





# Director's Corner

Paul Ho, Director General of EAO

The EAO has now successfully operated the JCMT for 16 months. It has been a very busy and rewarding time. The Observatory executed 5 calls for proposals, including one for Large Programs. The proposal pressure remains high with an oversubscription rate of about 3 in spite of so many closely-spaced calls. This is testament to the growth of a large new community in East Asia, vibrant in leading their own programs. We are particularly happy to see growing collaborations between the old and new JCMT communities, as well as between the East Asian regions. In particular, for each of the seven new Large Programs that were selected from 19 proposals, participation has been complete across all the regions. Substantial data have already been accumulated for many of these Large Programs because of an unusually excellent winter season on Maunakea.


*Figure 1: Birthday cake at the staff celebration of the EAO's first birthday.*

SCUBA-2 continues to operate smoothly, and POL-2 has just now been commissioned, providing new, exciting capabilities in wide-field polarizations studies. During the past few months, however, our heterodyne receivers have exhibited some persistent problems. These are being addressed by our engineers, but, almost in anticipation, an external instrument development panel, led by Richard Hills, has completed its deliberations, and has proposed the plan to (1) replace RxA with a new closed-cycle dual frequency system, (2) upgrade HARP with more pixels, dual polarization, and better mixers, and (3) upgrade SCUBA-2 with more pixels and better system sensitivity. The EAO and JCMT Boards endorsed these proposals, and the Observatory is moving ahead to implement. Our aim is to provide a ten-fold improvement in sensitivity across our instruments.

The JCMT staff continue to hold workshops in the regions to promote community engagement and science production. Tutorials are being placed on the web in order to provide help for new users. JCMT Legacy Data are continually being released to the community. We are working on providing more services to the local Hawaiian community via our participation in Kama'aina Tours of JCMT, Hawaiian Scholars program, high school student access to JCMT time, student internships with our staff, and outreach to the public.

In terms of personnel; in this past semester, we hosted Kuan-Yu Liu, a receiver engineer posted to JCMT from Taiwan, as well as two graduate student interns, Shao-Liang Li and Kevin Lacaille, posted from China and Canada. These staff have helped in supporting our work with the telescope, but also represented new opportunities for hands-on engagement for young people from all of our communities. Our own Jessica Dempsey has been appointed as JCMT Deputy Director, and Jess has also just been named one of the Women Who Mean Business for 2016 in Hawaii. We are very proud of that. That is the news, and we look forward to our next update.


*Figure 2: EAO/JCMT staff at the Hilo office in Hawaii, June 2016.*

# EAO takes JCMT to new heights

Jessica Dempsey, EAO/JCMT Deputy Director

It has been an unprecedented year for the JCMT. A year and more into EAO's operation of our facility, the numbers speak for themselves. Herculean efforts by our staff resurrected the telescope from mothballs in only three weeks to successfully participate in the Event Horizon Telescope VLBI in March 2015. What followed is a bit of a blur! Five Calls for Proposals, four of them in our first six months of operations, and yet oversubscription has remained the highest we have ever seen. In total, over 20,000 hours of science time was requested, from 449 P.I.s. JCMT has maintained its visiting observer support model, and it has been a pleasure to meet and work with a host of first-time JCMT observers, as well as our returning friends from the UK and Canada. Over 130 observers have visited since operations re-started.

The Large Programs benefited from the driest winter on record, and the community engagement in the programs is unparalleled. More than 600 astronomers are collaborating in the seven projects. We have worked hard to encourage inter-regional collaboration in both the Large and P.I. programs throughout the year. We have already seen the benefits of these partnerships and a measure of its success. An interesting way to analyze the collaborations is given in Figure 3, which shows chord charts of the P.I. inter-regional collaborations for 16A (left) and 16B (right), respectively. It shows how inter-regional collaborations are increasing (and hopefully we will see this continue to do so). Figure 4 shows the involvements from each EAO and JCMT partner region in the seven Large Programs. The total number of astronomers committing to the programs is in good proportion of the size of each

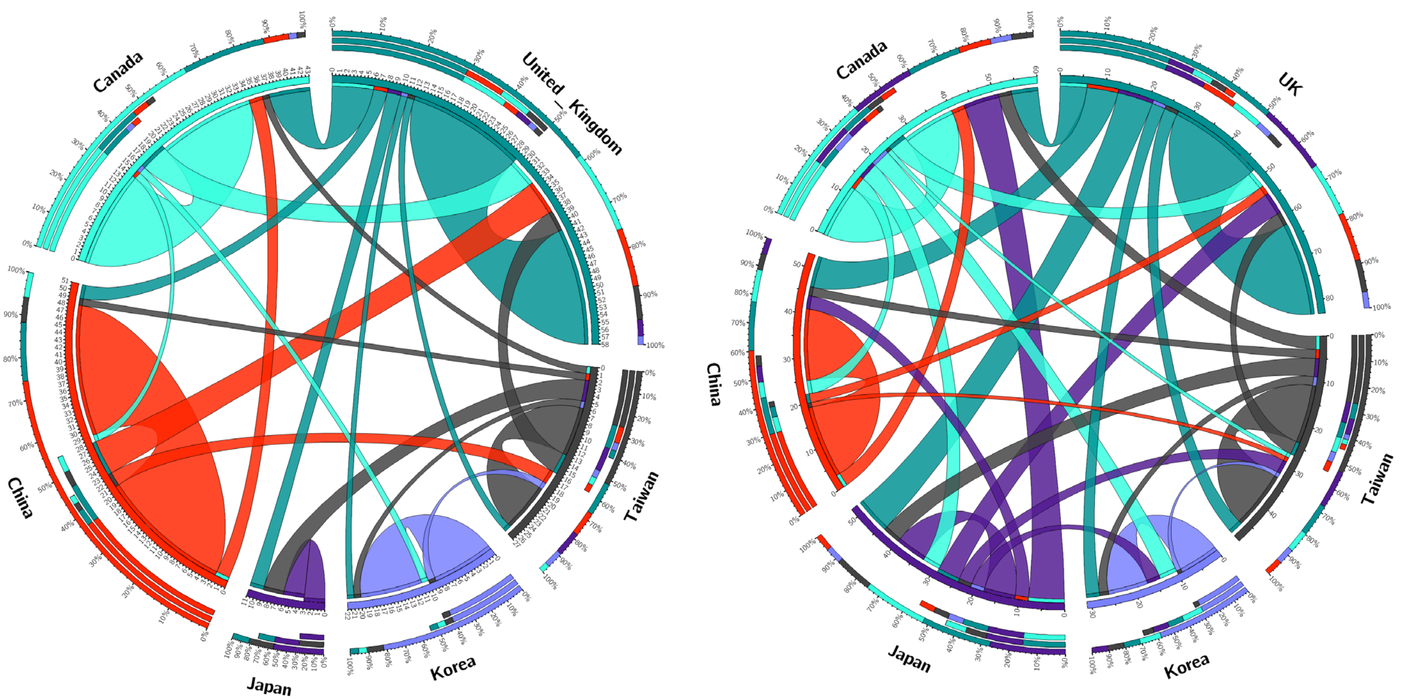



*Figure 3: These chord charts describe the inter-regional distribution of investigators in P.I. programs submitted to the 16A (left) and 16B (right) proposal rounds. The colored arcs represent the number of proposals with either PIs or co-Is from a given region [Clockwise from top: United Kingdom (dark cyan), Taiwan (dark grey), Korea (lilac), Japan (purple), China (red) and Canada (light cyan)]. The length of an arc indicates the number of proposals the region was involved in. Ribbons joining two arcs represent a collaboration in a proposal, with the color indicating the P.I. regional affiliation. The width of the ribbon indicates the relative number of proposal collaborations between regions. If a ribbon returns to its own colored arc, collaboration only occurred within a region's own community, not without. Ideally, one would hope to see an increase in collaborations as the effect of good incentive policies is felt, and this is indeed indicated in the increase in both the width and number of cross-arc connections between the left and right diagrams.*

community, and gratifyingly, there is quite even proportions of regional involvement in each of the seven programs (Dempsey et al., 2016).

We are now nearing the end of the 16A semester and looking to the next big steps for the Observatory. Part of this future includes ramping up the JCMT Future Instrumentation project. This ambitious project looks to keep JCMT at the bleeding-edge of submillimeter, single-dish astronomy by enhancing and updating our heterodyne and continuum instrumentation. Our first steps start with the replacement of our 230GHz receiver, RxA. This new receiver, a 3-cartridge ALMA-style dewar with insert space for three separate observing-band receivers, will provide increased performance and bandwidth, as well as strong synergy for the Event Horizon Telescope and other VLBI partnerships. Additionally, we are continuing to look to upgrades to our flagship camera, SCUBA-2, and undertaking a design study for a big (BIG!) 345GHz heterodyne array replacement for HARP. Watch this space for details as we proceed.

Overall, I have been just overwhelmed by the efforts of the JCMT scientists, engineers and support staff in this last year. We have had to adapt to a quite astonishing range of changes in the last years, with limited resources, and the creativity and resourcefulness of the East Asian Observatory staff has met each and every challenge. Secondly, the new and burgeoning East Asian community of astronomers has been a source of inspiration and enthusiasm which gives me strong hope for the future of the JCMT.

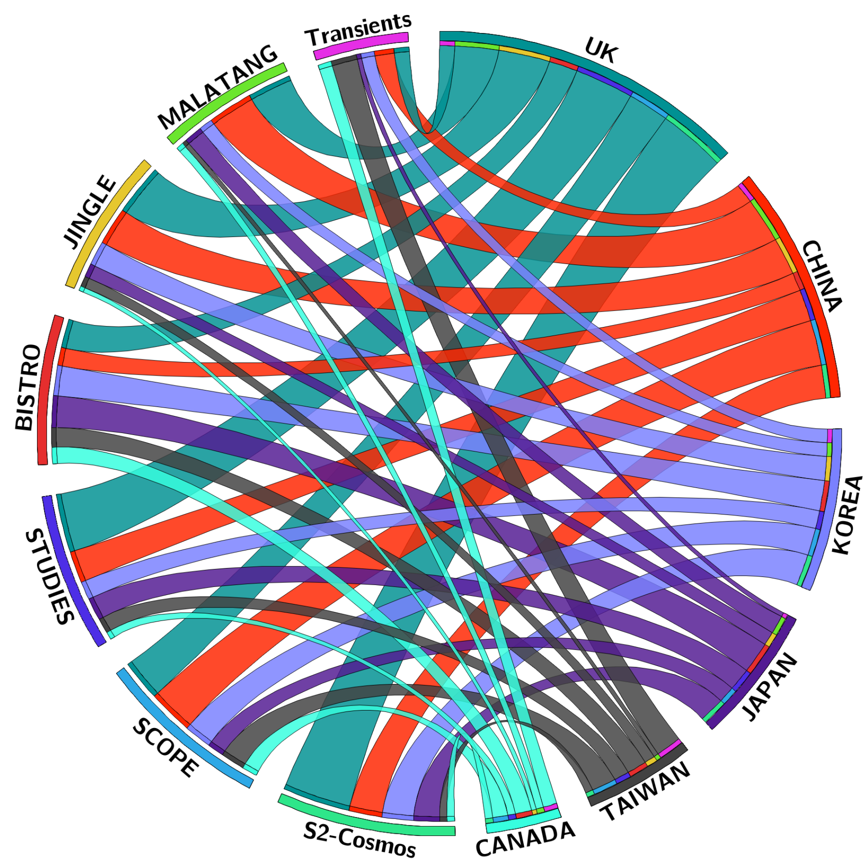



*Figure 4: This chord chart details the relative regional involvement in the seven Large Programs awarded time. The regions arc lengths indicate the relative number of astronomers from that region involved in the programs [Clockwise from top: United Kingdom (dark cyan), China (red), Korea (lilac), Japan (purple), Taiwan (dark grey) and Canada (light cyan)]. The numbers of astronomers involved are those following the opportunity for open-enrollment. Ribbons from each region arc indicate to which proportion each region is involved in the seven programs (the arcs on the left hand side of the chart). Perfectly proportional regional collaboration in each Large Program would result in ribbons of equal width linking each of our partner regions (on the right) to each Large Program (on the left). The chart indicates that our efforts to encourage proportional regional collaboration in each Large program have, to a large degree, been successful.*


*Figure 5: Jessica Dempsey was given the 2016 "Woman to Watch" award at the annual "Women Who Mean Business" event from the Pacific Business News.*

# From PMO to JCMT - contributing to FTS-2 commissioning effort

Shao-Liang Li,  EAO Visiting Student from Purple Mountain Observatory

My name is Shao-Liang Li and I have been an “East Asian Observatory Visiting Student” for the past three months. I am coming to the end of my stay here in Hilo and am soon to return to Purple Mountain Observatory (PMO), Chinese Academy of Sciences where I am currently in my final year of my PhD studies.

My background is in Fourier Transform Spectroscopy with the focus of my PhD studies being Fourier Transform Spectrometers (FTSs) and their applications in millimeter and sub-millimeter detection. At our lab back at PMO we have several FTSs fabricated by University of Lethbridge, who also fabricated the FTS-2 here at JCMT. FTS-2 is an ancillary instrument to the sub-millimeter camera, SCUBA-2.

*Figure 6: Shao-Liang Li working hard in the Visitors Office at EAO.*

*Figure 7: Kevin Lacille - another EAO Visiting Student. Kevin is working on POL-2 comissioning data as part of his time at EAO as a six month visiting student from Dalhousie University, Canada.*

During my stay my work has focused on improving on the port imbalance suffered by FTS-2. Ideally the power received by the two respective sub-arrays should be identical – as they look at the same sky. To address this imbalance in power we have looked at i) Pointing with FTS-2 in the beam ii) Rotating the beamsplitter iii) Replacing the transparent cover with the original aluminum one, to see if any outside radiation contribute to the imbalance issue.

As with all large projects we did have some bumps with the FTS during my stay. An upgrade to the motor controller to the drive pick-off mirror and the return of one of the beam-splitters that was sent to Cardiff University for testing delayed the on-sky work. With FTS-2 recently back in operation I have had a busy end to my time here in Hawaii.

During these three months I have been staying in the East Asian Observatory house – along with two fellow East Asian Observatory visitors. The house is in a great location and it is my first time to see an actual lichee tree that is gorgeous! I also have use of an East Asian Observatory bike which makes it possible for me to join the “lunch ride folks” – a group of Hilo Astronomer and bike enthusiasts – riding with this group has been a lot of fun, although quite challenging. As for the beaches they are fantastic!

I have thoroughly enjoyed my time working at the East Asian Observatory. The staff are very friendly and supportive and I feel I have benefited greatly from getting a hands-on understanding of how an observatory functions. The office in which I work enables me to interact with the many visiting observers who come to use the telescope as an observer for their own PI program or for one of the seven “Large Programs”. When I return to the Purple Mountain Observatory I look forward to sharing my knowledge and my experiences. The opportunity to assist with the FTS-2 commissioning has been very valuable to me and I would like to thank everyone who made this opportunity possible.

# The JCMT's Users Meeting, Japan

Harriet Parsons, JCMT Support Scientist

In April 2016 the East Asian Observatory held its first JCMT users meeting at NAOJ, in Japan. The meeting was a chance for JCMT astronomers to come and hear the latest news from the observatory, share their own science results and interact with fellow astronomers from across the various EAO regions and partners.

Some participants at the users meeting already had six days of EAO/JCMT meetings under their belts – with the EAO Board and JCMT Board being held the week prior. The presentations given by the Large Program and PI scientists proved be the highlight as Board members could see first hand, all their efforts being turned into great science.

The last time EAO staff visited Japan, just before the handover to EAO over a year ago, the intention was to introduce the JCMT, its capabilities and nuances to a new community of astronomers. We provided workshops on how to propose, plan for, take and produce scientific products. This latest meeting demonstrated how successful and integrated the EAO astronomy community has become in such a short time.

In addition to two days of science talks the users meeting included a one-day data reduction workshop. This workshop formed the basis of the new JCMT Data Reduction/Analysis Tutorials webpage: www.eaobservatory.org/jcmt/science/reductionanalysis-tutorials/. This is a great place for new users (and students) to get hands-on experience with the JCMT's data reduction software.

Other highlights from the meeting included the discussion of the future for instrumentation at the JCMT - discussed by Ming-Tang Chen. JCMT astronomers will be pleased to hear of a new 230GHz receiver (compatible with VLBI) to be installed at the JCMT before the end of 2017. Also discussed was work to upgrade the SCUBA-2 filters and a study for a new 45 pixel 345GHz array.

There were many fantastic science talks given at the Users Meeting and it was clear that the new EAO community is active, vibrant and engaged with access to the sub-mm sky from Maunakea. Particularly interesting were the talks linking the JCMT with the other telescopes on Maunakea – notably Hyper-Suprime Cam on Subaru. Minju Lee – From the University of Tokyo – gave a talk on behalf of the MAHALO-JCMT project (led by Tadayuki Kodama) a JCMT extension to the MAHALO-Subaru project (MApping HAlpha and Lines of Oxygen with Subaru). This project is using JCMT to take deep sub-mm images of dusty starbursts in Proto-clusters at redshifts between 2 – 6.

The other exciting news that broke at the JCMT Users Meeting was the announcement of the POL-2 program BISTRO obtaining the first few hours of data. Obtaining this data was a milestone for two reasons i) all seven Large Programs were now obtaining data and ii) this is the first science data to be taken outside of commissioning – leading the way for POL-2 science in Semester 16B.

If you were unable to make it to this Users Meeting I encourage you to take a look at the EAO web pages. Slides from all the presentations given at the JCMT Users meeting are available online at: www.eaobservatory.org/jcmt/science/users-meeting-2016/

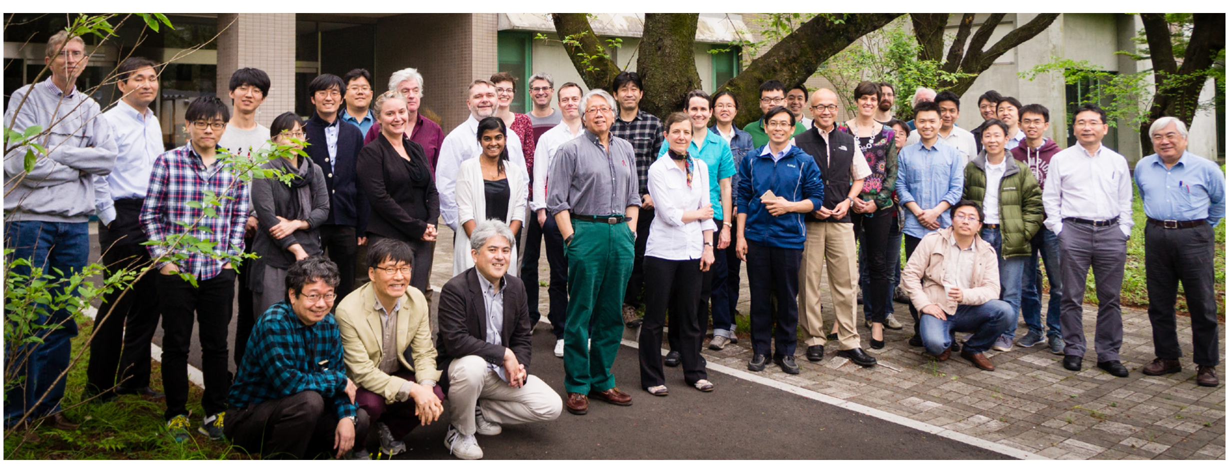


*Figure 8: EAO staff and JCMT astronomers at the first JCMT Users Meeting, hosted at NAOJ in Mitaka, Japan.*

# STUDIES - the SCUBA-2 Ultra Deep Imaging EAO Survey

Wei Hao Wang, on behalf of the STUDIES consortium,

STUDIES objective is a confusion limited 450-micron map at the center of the COSMOS field within the CANDELS footprint using 330 hours of Grade 1 weather. This takes advantage of the high angular resolution of SCUBA-2 at 450 microns, comparing to Herschel at 350 and 500 microns, and allows detections of faint galaxies with a higher surface density. Our goal is to reach an rms of 0.57 mJy at the center of a daisy pointing, to detect the dominant members in the dusty galaxy population that give rise to the bulk of the far-IR extragalactic background light. Such a deep 450 microns map will enable the detections of nearly all $L_{IR} > 10^{12}$ $L_{\odot}$ galaxies at $z < 4$, and the majority of $L_{IR} > 10^{11}$ $L_{\odot}$ galaxies at $z < 2$. There will be a substantial overlap between galaxies detected by STUDIES and by deep optical surveys in their star formation rate. This will provide a more complete census of the cosmic star formation that is obscured and unobscured by dust.

As of June 2016, we had obtained roughly 130 hours of data and the program is 40% complete, thanks to the El Niño and the efficient queue system. The map is fully reduced (Fig.9). This version of reduced image was delivered to the team members in early June. Source extraction and construction of the source counts are underway. In this map, we reach an rms of 1.0 mJy at the map center (Fig.10). Since this is consistent with the SCUBA-2 ITC, we expect to reach our final goal of rms = 0.57 mJy once we collect all of our data. We also closely monitored the effect of confusion as our map became deeper. So far we have not seen a noise floor that indicates the confusion limit. We are therefore quite optimistic about reaching our final goal after three years of observations.

The collaboration between the team members also move on very well. We now have 98 investigators on our team. We had set up a wiki page to store documents, to update the project status, and for team members to announce the scientific studies they would like to carry out. An ALMA followup proposal was submitted for cycle 4, as a collaboration between the STUDIES team and the S2CLS team. More multi-wavelength followup observations will be proposed to various observatories in the upcoming proposal cycles.

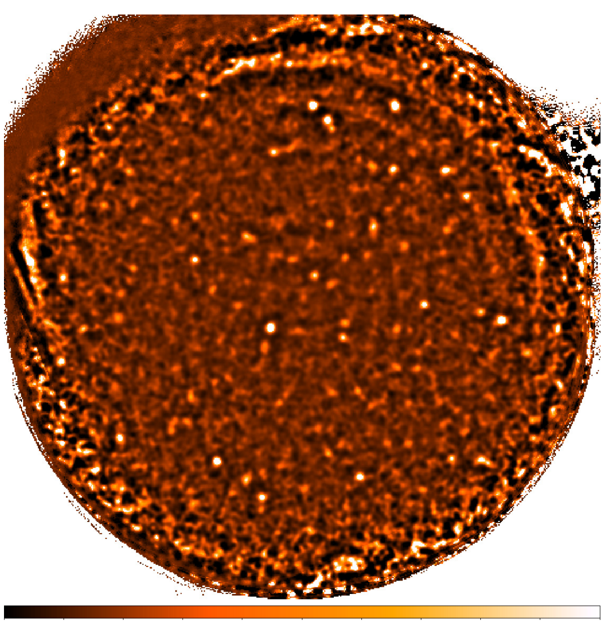



*Figure 9: Latest STUDIES 450 um image. The total diameter of the map is 15 arcmin. The color scale is in unit of mJy/beam. The noise at the map center is 1 mJy. Roughly 40 sources are detected. Because of the steep counts in the submillimeter, we expect the number of detected sources to dramatically increase after we further deepen the image in 2017 and 2018.*

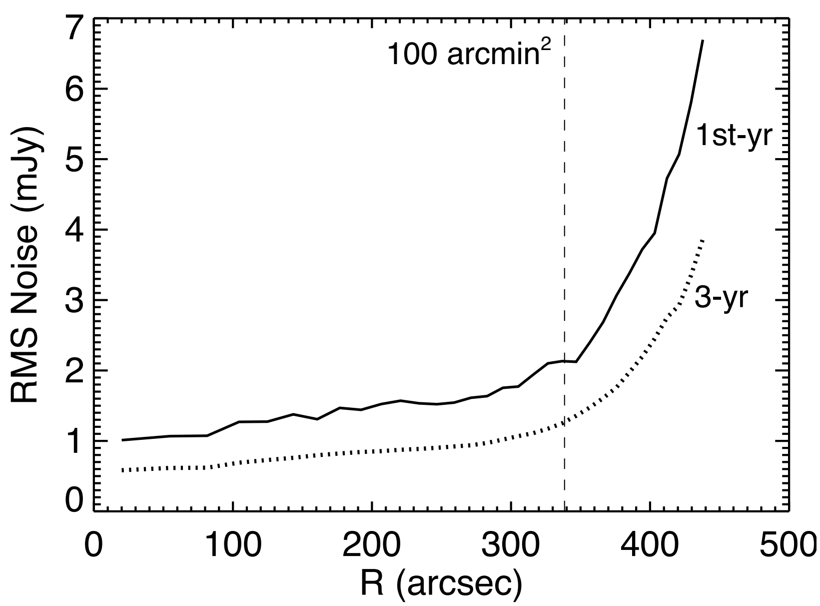



*Figure 10: The distribution of rms noise in Fig. 9 (solid curve) and the expected rms after we complete the survey in three years (dotted curve). The vertical dashed line indicates the radius where the survey area is 100 arcmim².*

# SC2-COSMOS

Yuichi Matsuda,on behalf of the SC2-COSMOS consortium,

SC2-COSMOS is an EAO SCUBA-2 survey of ~1,000 submillimetre galaxies in the 2 degree2 COSMOS field. COSMOS is the pre-eminent ALMA-visible, degree-scale extragalactic survey field. The goals of the SC2-COSMOS are to first complete a 1.5-mJy rms 850micron map of the full COSMOS field (partly covered by SCUBA-2 Cosmology Legacy Survey, S2CLS) and to then increase the depth of this map to 1.2mJy rms. This map will have twice the area of similar surveys in a single contiguous field, allowing unique tests of the clustering of the submillimetre galaxy population on scales up to ~ 60 Mpc.

We have advertised SC2-COSMOS through a combination of national mailing lists and targeted recruitment. We had 111 members (triple the number of those named on the initial proposal), split ~60:40 between "new" and "old" JCMT partner communities: China (22), Japan (15), Korea (20), Taiwan (5), Canada (5) and UK (44). The equivalent numbers from the original proposal were: China (9), Japan (6), Korea (3), Taiwan (2), Canada (1) and UK (16), illustrating the success of broadening the team.

The observations are now ~70% complete. Preliminary dataset (v0) were produced by Chian-Chou Chen with data taken up to the middle of March 2016. The dataset were released to the collaboration on the wiki at the end of March for the first science analysis. The rms is 1.5-1.7mJy on three of the quadrants and is ~2mJy on the final (north-east) pointing. Based on the dataset, we have submitted 3 ALMA follow-up proposals.

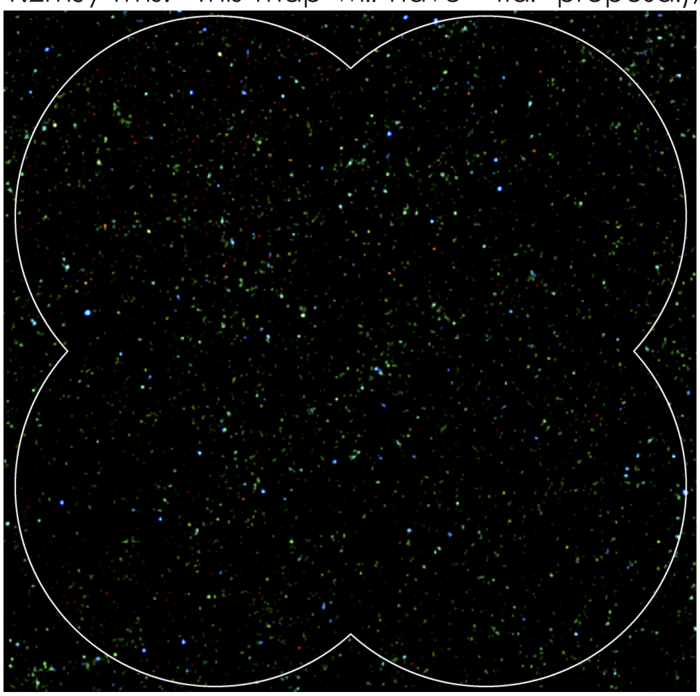


*Figure 11: A "true-colour" image of the COSMOS field created from SCUBA-2 850um (red) and Herschel SPIRE 250 and 350um (blue and green respectively) maps. This map highlights the rare, red dusty sources which are likely to include some of the highest redshift examples of this population. The wide-field available in COSMOS allows us to use SCUBA-2 to construct a large sample of these sources needed to understand their nature and to study their environment. The white line shows the coverage of the 1.4x1.4 degree SC2-COSMOS map.*


*Figure 12: Left, Yuichi Matsuda presents the SC2-COSMOS Large Program at the JCMT Users Meeting in Japan. Right, participants during another of the talks at the JCMT Users Meeting.*

# JINGLE - the JCMT dust and gas In Nearby Galaxies Legacy Exploration

Ting Xiao, on behalf of the JINGLE consortium

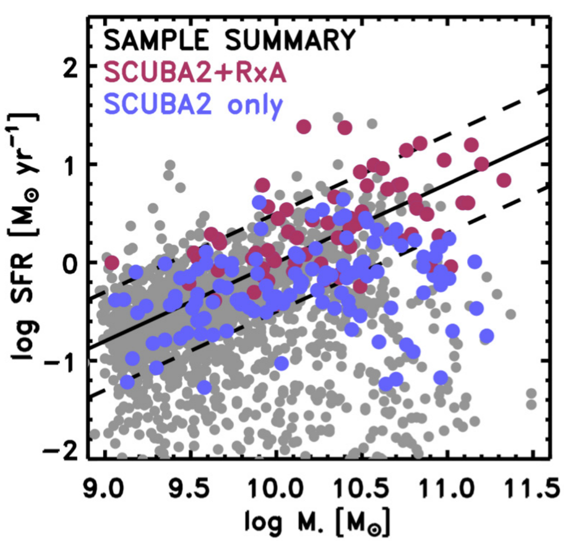
JINGLE is a new JCMT legacy survey designed to systematically study the cold ISM of galaxies in the local Universe.

Over the next three years and with 780 hours of observing, JINGLE will provide integrated 850μm continuum measurements with SCUBA-2 for a representative sample of 192 Herschel-selected galaxies, as well as integrated CO(2-1) line fluxes with RxA for a subset of 62 of these galaxies. In addition to the Herschel/SPIRE photometry from the H-ATLAS survey, the sample is selected out of fields targeted by the MaNGA optical integral-field spectroscopy survey. By combining the JCMT data products with all these ancillary data, JINGLE will allow for a detailed characterisation of the gas and dust properties of galaxies in the local universe, in connection with their kinematic, structural and chemical properties. The scaling relations between dust, gas, and global physical properties will provide critical benchmarks for high-redshift studies with JCMT and ALMA.

As of April 2016, JINGLE observations are 13% complete with all data so far taken with SCUBA-2. The detection rate at 850 microns is 80%, with a quarter of these galaxies also detected at 450μm due to the outstanding weather on MaunaKea during the semester. Combining the SCUBA-2 and Herschel data, we fit modified blackbodies and simultaneously obtain constraints on dust temperature and emissivity index.

First science results will include scaling relation between dust properties and a range of global galaxy properties including stellar mass, metallicity, and specific SFR. Once the RxA component of the survey is under way, JINGLE will further investigate the link between dust and gas masses across the local galaxy population, and their impact on star formation.

The team will hold the first face-to-face meeting this October (Oct. 17-18) at Shanghai Astronomical Observatory, CAS, to discuss the first quartile survey progress and early science results based on the data taken till then. The meeting will cover topics including data reduction and data quality evaluation, survey status and detection rates, gas and dust properties and their scaling relations, correlations between gas properties and internal galaxy properties, and any other scientific topics that could be investigated using the survey data.



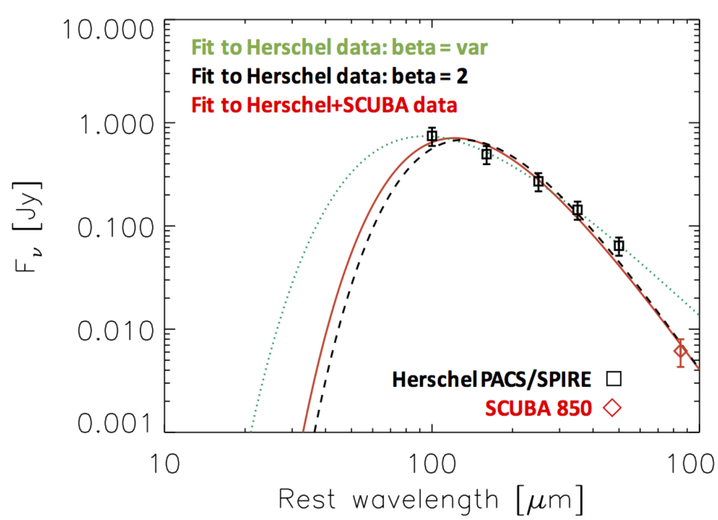




*Figure 13: Left: Distribution of the targeted and parent samples in the SFR-$M_*$ plane. The final sample includes 190 galaxies for SCUBA-2 observations (magenta and blue symbols), a subset of which will also be targeted by RxA for CO(2-1) (magenta symbols). Right: Preliminary result on one target (J13081.65-264555.3) shows the SED fitting combining Herschel and SCUBA2 data. It suggests the combined data is more consistent with modified-blackbody model with dust emissivity index beta=2 (red line), and gives more accurate dust mass measurement. (Credits to Ilse De Looze).*

# MALATANG

Thomas Greve, on behalf of the MALATANG consortium

Foodies and gastronomers alike will recognice malatang as a popular type of Chinese street food. If said foodies happen to be astronomers they may also know MALATANG (MApping the dense moLecular gAs in The strongest stAr-formiNg Galaxies) as one of the seven large programs approved at the JCMT in the fall of 2015. Here we shall briefly summarise the scientific motivation and scope of MALATANG, its current status, and the road ahead for the program. This was presented in a talk at the JCMT User Meeting at the NAOJ in Mitaka in April 2016. MALATANG was born out of the realisation that our understanding of the dense (> $10^4$ $cm^{-3}$) star-forming gas phase in nearby galaxies is hampered by the lack of spatially resolved observations of its molecular line tracers such as HCN and HCO+. Most studies have relied on pointed single-dish observations of the bright central regions of galaxies in order to ensure robust detections of the aforementioned lines, which tend to be significantly weaker than CO and therefore require long integration times. While millimeter interferometers such as ALMA and NOEMA provide both the necessary sensitivity and angular resolution to detect and resolve the HCN and HCO+ lines, their small fields of view imply that in practice an exorbitant amount of observing time is required to map an extended nearby galaxy, let alone a statistically significant sample of them. As a result of this dearth in the number of resolved HCN and HCO+ studies of nearby galaxies, the picture we have of the dense gas and its star formation capabilities is bound to be biased as it is based on the high pressure excitation conditions typical of galaxy nuclear regions. How this picture changes in quiescent disk conditions is something we presently are in the dark about and it is the key scientific driver of MALATANG.

The total amount of JCMT time dedicated to MALATANG is 390hr, which will be spent using the 350GHz heterodyne array HARP to map the HCN and HCO+ J = 4 - 3 line emission in 23 of the nearest IR-brightest galaxies beyond the Local Group. The ~14" beam size of the JCMT at 350GHz and the target sensitivity of 0.03 K km/s implies that MALATANG will probe the dense gas on linear scales of 0.2 - 2.8 kpc and down to masses of ~$5\times10^6$ $M_\odot$. The systematic mapping of the distribution of dense gas out to large galactocentric distances in a statistically significant sample of nearby galaxies makes MALATANG a unique survey, and as such it is bridging the gap in physical scale and luminosity between extragalactic (i.e., galaxy-integrated) and Galactic (i.e., single molecular cloud) observations. An important outcome of the survey will be a characterisation of the distributed dense gas star-formation relations, as traced by the HCN and HCO+ J = 4 - 3, across our targets. From low surface density environments in disks to nuclear regions where surface densities are high, MALATANG will yield new insight into whether such environments harbour fundamentally different star-formation modes and efficiencies.

Observations of MALATANG (project ID: M16AL007) began

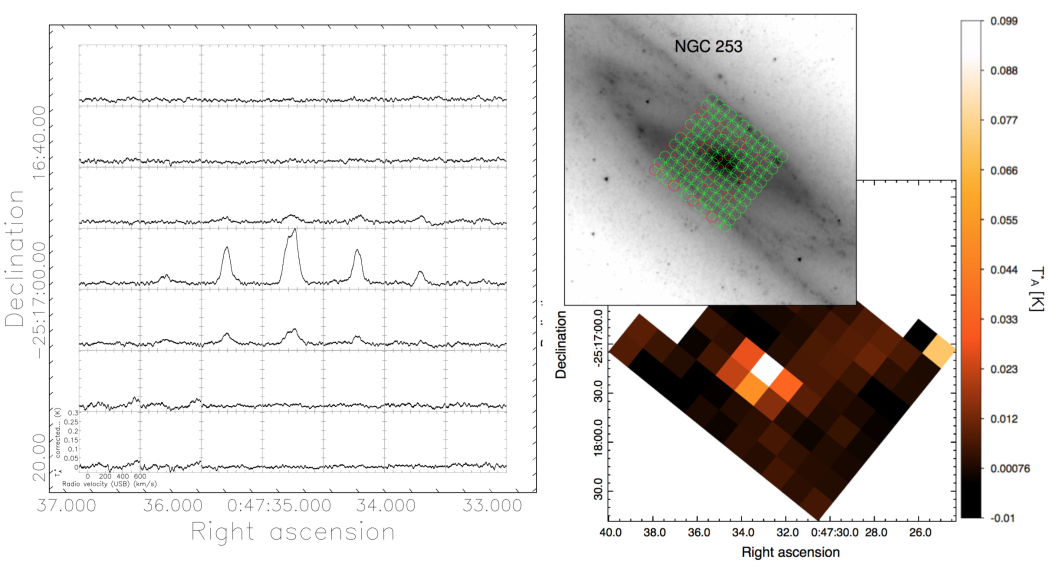



*Figure 14: Preliminary MALATANG data of the nearby galaxy NGC253, showing the HCN J = 4-3 spectra in 10" pixels across a ~ 70"×70"region (left), the collapsed HARP data cube (bottom right), and the jiggle observing mode footprint pattern of HARP overlaid on an optical image of NGC 253 (top right).*

on Nov. 28th 2015. This earlier than expected start was made possible due to SCUBA-2 having warmed-up and RxA being down for maintenance, which left HARP as the only available instrument. Approximately 24% (~90 hours) of the 390 hours of time allocated to MALATANG has currently been observed. HCN(4-3) and HCO+(4-3) data have been acquired for the following sources: Arp299, IC342, NGC1068, NGC1097, NGC1808, NGC1365, NGC2146, NGC2903, NGC3627, NGC3628, NGC660, NGC 891, Maffei2, M 82, NGC 253. The data are processed through our customized Starlink ORAC-DR data reduction pipeline. Fig. 1 shows preliminary HCN J = 4-3 data obtained for the nearby starburst galaxy NGC 253. As is the case for most of our targets, HCN (and HCO+) are strongly detected in the central regions but rapidly weaken further away.

At the time of writing MALATANG consist of 91 astronomers (of which 13 are graduate students) with participation from all of the JCMT stakeholders, i.e.: UK, CA, CN, JP, KR, TW and the EAO. With more than half a dozen papers having been proposed within the MALATANG team, we expect a flurry of activity in the next 12 months as data flow in and data products converge towards finalization. A first MALATANG face-to-face meeting is expected to take place in October in China focussing on data management as well as current and future MALATANG papers.

# B-fields In STar-forming Region Observations: BISTRO

Ray S. Furuya and Derek Ward-Thompson on behalf of the BISTRO consortium

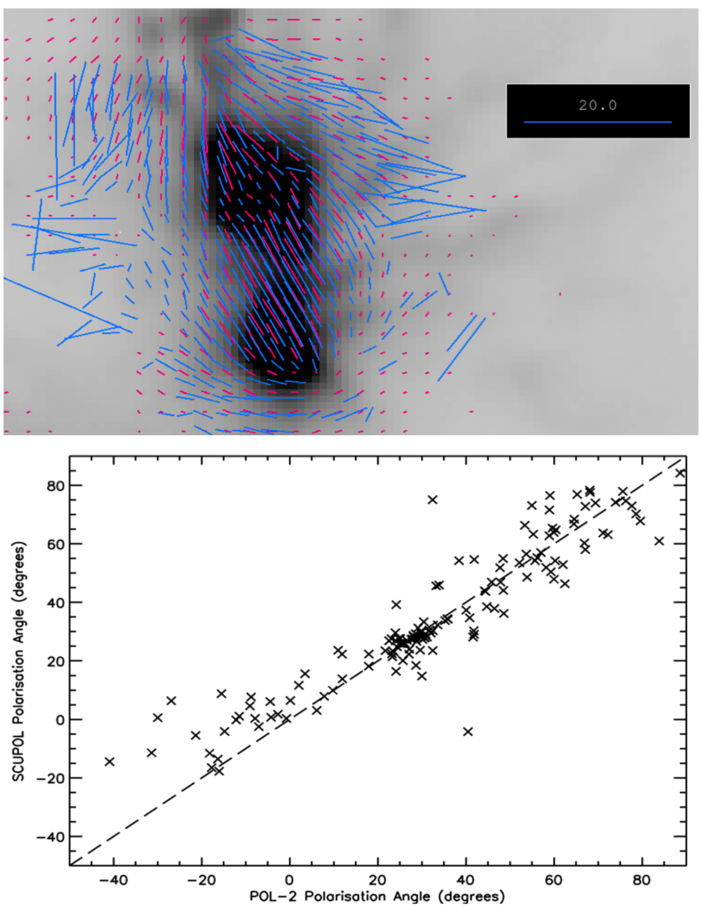



*Figure 15: Top - A comparison of the polarization direction maps obtained by SCUBAPOL (the blue "vectors") and those by POL-2 (the red "vectors") towards the Orion BN/KL region. Bottom - A plot of polarization position angle in the BN/KL region as measured by SCUBAPOL and by POL-2. Good agreement is seen.*

Without accurate, detailed knowledge of the collapse process of molecular clouds, we cannot understand exactly how a star forms. One of the major limiting factors is that the exact role of magnetic fields (B-fields) in this process is not fully understood, even from a theoretical perspective. There has been a long-standing debate about the role of magnetic fields in the star formation process.

Two extreme model scenarios ("strong" B-fields and "weak" B- fields) have been proposed. The former corresponds to "slow" star formation, where the collapse of a core starts when the core loses support by magnetic pressure through ambipolar diffusion. The latter is known as "fast" star formation, where turbulence or turbulent magnetic reconnection puts a core into a "supercritical" state, from where it can collapse under its own self-gravity. Currently, the debate centres around identifying at which point in the cloud core collapse process magnetic fields play a dominant role. Observations have demonstrated that B- fields exist in star formation regions (through polarization measurements and the detection of the Zeeman effect). However, observations have not yet fully assessed which of the above two scenarios, if either, occurs in real star formation regions.

In this context, we are currently using the newly installed SCUBA-2 polarimeter, POL-2, to unveil the polarization structure towards the innermost, densest parts of all of the Gould Belt star-forming regions that we have previously mapped with SCUBA-2 and HARP-B in our previous JCMT Gould Belt Survey (Ward-Thompson et al., 2007). The goals of the project include tracing the direction of the magnetic field and the strength of the field in the centers of all of these regions (via the Chandrasekhar-Fermi method). This will answer currently open questions in star formation, such as the issues mentioned above.

POL-2 with SCUBA-2 on JCMT is a unique facility, as it is the most sensitive facility world-wide that can map the magnetic field within cold dense cores and filaments on scales of ~1000 AU in nearby star-forming regions, such as Taurus and Ophiuchus. This size scale is crucial for testing models such as the filamentary star formation model, because we know from optical and near-infrared polarization studies that the pc-scale field lies roughly perpendicular to the overall typical filament directions, but we do not know what happens to the field within the dense gas of the filaments themselves, nor what happens within the cores that form in the filaments. This is crucial to understanding the physical processes taking place, and to discriminating between the models.

There is also a debate about the role that the B-field plays in shaping proto-stellar evolution once proto-stars have formed, and about its effect on bipolar outflows. For example, recent studies find no correlation between outflow and magnetic field directions on scales less than 1000 AU, while there is correlation on scales of ~10,000 AU and above. One explanation of this apparent conflict in the field morphology uses detailed modeling of toroidally wrapped B-fields at the centres of clouds. This has been used to explain early disk formation in Class 0 proto-stars in a recent model in which early disks are hypothesized to be formed preferentially in fields misaligned with the outflow directions.

The legacy value of this large-scale homogeneous data-set will be huge. All future models of the role of magnetic fields in star formation will be forced to explain these observations in all of the nearest star-forming regions. We have now started science observations. We have verified that POL-2 is consistent with SCUBAPOL in part of Orion (Fig.1 a & b). We are currently still refining the instrumental polarization as a function of elevation and position within the field of view of SCUBA2, as we systematically map other regions.

# SCOPE: SCUBA-2 Continuum Observations of Pre-protostellar Evolution

Ken Tatematsu, Tie Liu, on behalf of SCOPE team

Stars form in dense regions within molecular clouds, called pre-stellar cores (PSCs), which provide information on the initial conditions in the process of star formation. However, the formation and early evolution of dense cores in different environments are still not well known. In order to make significant progress in understanding the early evolution of molecular clouds and dense cores in a wide range of Galactic environments, we are carrying out an unbiased "all-sky" survey of the ~1000-2000 densest Planck cold clumps with the JCMT/SCUBA2 in 850 micron continuum (SCOPE) and with the TRAO 14-m telescope in J=1-0 of CO isotopo-

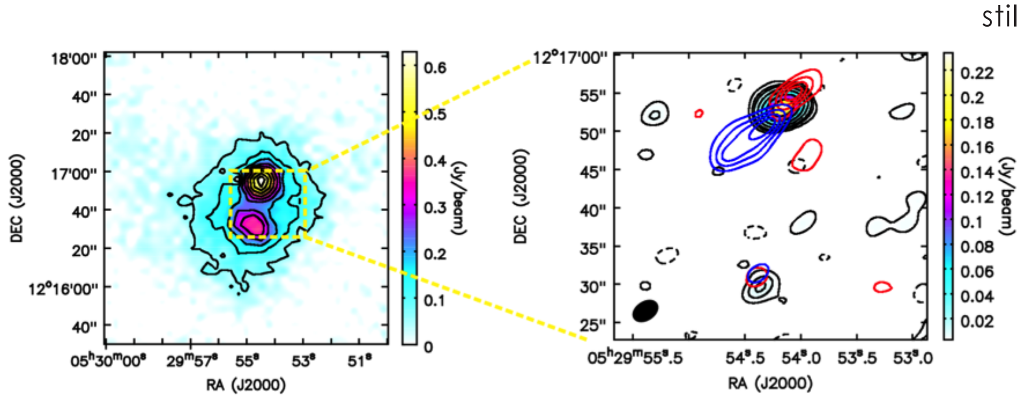



*Figure 16: Left panel: SCUBA-2 850 micron continuum of PGCC G192.32-11.88. Two dense cores (north: G192N and south: G192S) were detected. Right panel: SMA 1.1 mm continuum is shown as color image and black contours. CO outflows are shown in red and blue contours.*

logues (TOP). We are also actively developing follow-up observations with other telescopes (NRO 45-m, KVN 21-m telescopes, SMT, SMA, etc).

Hundreds of submillimeter dense cores have been identified in SCOPE. Most of them are classified as starless cores or very young (Class 0) protostellar cores on the basis of Spectral Energy Distributions (SEDs) from WISE, Spitzer, Akari data base. For example, we discovered an Extremely Young Class 0 Protostellar Object (G192N) and a Proto-brown Dwarf Candidate (G192S) in the Bright-rimmed Clump PGCC G192.32-11.88 (Liu et al. 2016, ApJS, 222, 7; see Fig 17). These dense cores are being followed-up by using various ground-based radio telescopes. We are characterizing their chemical and dynamical evolutionary stages by utilizing molecular column density ratios and detailed analysis of dynamics from spectroscopic observations. We show an example of the Nobeyama 45 m telescope follow-up in Fig. 17.

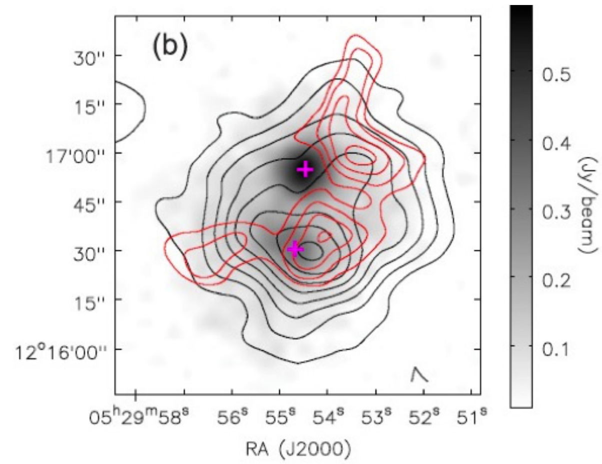



*Figure 17: PGCC G192.32-11.88 observed with JCMT SCUBA-2 and Nobeyama 45 m telescope. The gray scale shows SCUBA-2 850 micron continuum map, black contours show N2H+ distribution, and red contours show HC3N distribution.*

# A TRANSIENT SEARCH FOR VARIABLE PROTOSTARS: HOW DO STARS GAIN THEIR MASS?

Gregory J. Herczeg and the TRANSIENT Team

Low-mass stars are formed through the gravitational collapse of molecular cloud cores. The evolution of mass accretion onto a forming protostar depends on the rate at which the interior of the core collapses, the significance of a circumstellar disk as a temporary mass reservoir and transportation mechanism, and the physics of how the inner disk accretes onto the stellar surface. In the seminal Shu (1977, 1987) model of gravitational collapse of a spherical protostellar core, the young star grows steadily from the infalling envelope at a rate of a few $10^{-6}$ $M_{\odot}$ $yr^{-1}$. However, Kenyon et al. (1990) found that luminosities of most protostars fall far below those expected from energy release by steady accretion over protostellar lifetimes. This Luminosity Problem has since been confirmed with an improved census of protostars (e.g., Enoch et al. 2009; Dunham et al. 2010). The resolution of the Luminosity Problem likely requires a time dependence in the accretion rate. Observationally, strong but mostly indirect evidence suggests that the accretion rate is punctuated by short bursts of rapid accretion (often termed episodic accretion; Kenyon et al. 1990; Dunham et al. 2010, 2012). The form of this time dependence may have a lasting effect on the evolution of stars (Baraffe et al. 2012) and their disks (Stamatellos et al. 2011; Vorobyov et al. 2013; Harsono et al. 2015).

The suggestion of accretion bursts in protostars has significant support from later stages of pre-main sequence stellar evolution. Spectacular outbursts, with accretion rates enhanced by factors of 100– 1000, can last for months (called EXors; Herbig 1950, 2008; Aspin et al. 2010; Kospal et al. 2014) or decades (called FUors, see review by Hartmann & Kenyon 1996). Because of observational biases in optical transient searches, these outbursts are detected only on stars that are optically bright and are at or near the end of their main phase of stellar growth. Only 2 outbursts have been detected on a deeply embedded Class 0 star, the stage when the star should accrete most of its mass (Fischer et al. 2012; Safron et al. 2015). Indirect evidence for outbursts includes chemical signatures of past epochs with

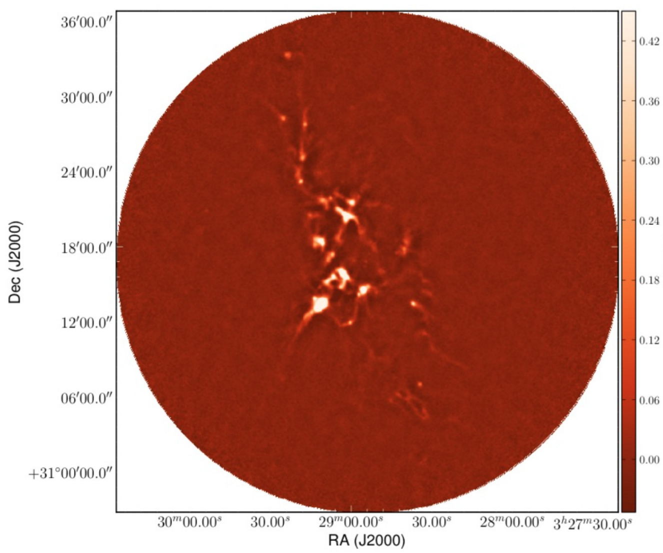



*Figure 18: The JCMT/SCUBA2 map of NGC 1333.*

high luminosity (e.g., Kim et al. 2011; Jorgensen et al. 2013; Vorobyov et al. 2013) and periodic shocks/bullets along protostellar jets, which may offer a historical record of accretion events (e.g., Reipurth 1989; Raga et al. 2002).

We are therefore using JCMT/SCUBA2 to pursue the first dedicated sub-mm monitoring program to measure accretion variability in protostars in eight fields within nearby star forming regions. These regions include a total of 182 embedded protostars (Class 0/I YSOs with envelopes) and 800 disks/flat-spectrum objects. The sub-mm photons from protostars are last emitted from cold dust in envelopes, but most of the energy is generated by accretion onto the protostar. Johnstone et al. (2013) found that an outburst in accretion luminosity heats the dust in the envelope, which is then seen as brighter emission at 850 µm. Far-IR and sub-mm observations provide a snapshot of accretion rate, averaged over the few-weeks heating timescale for the luminosity burst to propagate through the envelope. Since far-IR observations require the calibration stability of space telescopes and are not possible at present, sub-mm monitoring may be the only way to probe the earliest stages of stellar growth, since these stars are heavily embedded and not visible at optical/near-IR wavelengths.

The accuracy of the flux calibration is the key innovation for the success of this program. The default calibrations are accurate to ~ 10%, so that modest changes will be insignificant. Our program leverages the number of bright protostars in each region by measuring the relative source- to-source variability. This relative flux calibration is already achieving a flux calibration accurate to ~ 2% at 850 µm (see Fig 19).

Our survey will continue monthly monitoring of these regions for 3 years, while obtaining an even longer baseline through comparisons with data from the Gould Belt Survey. This cadence will allow us to search for changes on the brightest sources on month-long timescales, and to stack data to measure changes on weak sources on year-long timescales. The full dataset, when stacked, will be the deepest single dish sub-mm maps of these star forming regions, yielding serendipitous science related to protoplanetary disks, filaments, outflows, and very low luminosity protostars. This program is also motivating complementary research related to the physics of outbursts and the time-variable chemistry that would result from a large change in protostellar luminosity.

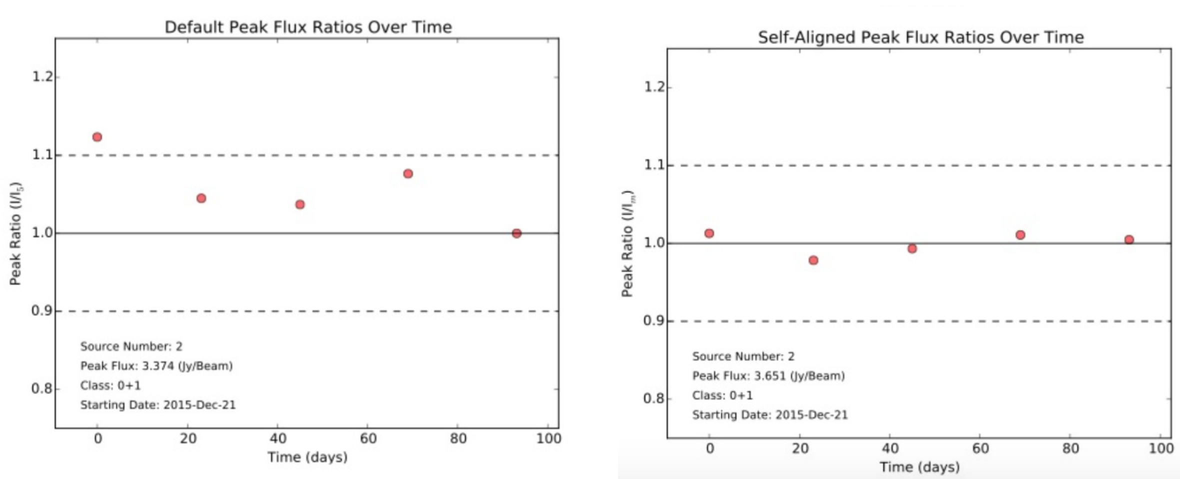



*Figure 19: Flux calibration for a source in NGC 1333. The left panel confirms that the default calibration is accurate to 10%, which is already an impressive achievement (Dempsey et al. 2012). We exploit the richness of our fields by calibrating fluxes relative to bright sources in the field, thereby achieving an accuracy of ~ 2%.*

# Resolved Analysis of the ISM and Star Formation Properties of Spiral Galaxies in Different Environments

Angus Mok and Christine Wilson

In the Universe, galaxies can be found in many different environments, from isolated galaxies, to groups of tens of galaxies, to clusters of thousands of galaxies. Observations have shown that overdense regions in the Universe are increasingly dominated by quiescent galaxies (Blanton & Moustakas, 2009). Since star formation is closely linked to the molecular gas content in nearby spiral galaxies (Saintonge et al. 2011; Bigiel et al. 2011), the cluster environment should have a strong effect on their interstellar medium (ISM). Processes such as ram pressure stripping, tidal interactions, and strangulation have been proposed to explain the environment's influence on the HI component, but their effects on the denser, more centrally located $H_2$ gas is less clear (e.g. Kenney & Young, 1989).

To study the effects of environment in the local universe, we use data from the Nearby Galaxies Legacy Survey (NGLS), an HI-flux limited sample of nearby galaxies (D < 25 Mpc). The CO J=3-2 line was mapped out to at least $D_{25}/2$ using HARP on the JCMT (Wilson et al. 2012). We select out spiral galaxies for comparison between the field, group, and Virgo subsamples. We also measure star formation rates from extinction-corrected Hα data (Sanchez-Gallego et al. 2012) and stellar masses from the $S^4G$ survey (Sheth et al. 2010).

We first looked at the integrated properties from the sample of gas-rich spiral galaxies. Compared to non-Virgo galaxies, galaxies in the Virgo cluster have higher $H_2$ gas masses and $H_2$ to HI ratios, perhaps due to environmental interactions that funnel gas towards the centre and aid in the conversion of atomic to molecular gas. They also have lower specific star formation rates (sSFR = SFR/$M_*$) and lower star formation efficiencies (SFR/$M_{H2}$), implying molecular gas depletion times ($t_{gas}$= $M_{H2}$/SFR) that are longer than non-Virgo galaxies (Mok et al. 2016). This suggests that the cluster environment is inhibiting the star formation process, perhaps due to differences in turbulent pressure or heating.

To study the resolved properties of these galaxies and further explore these environmental variations, we select 55 galaxies from the larger sample where we have maps of their $H_2$ or HI distributions. The HI maps come

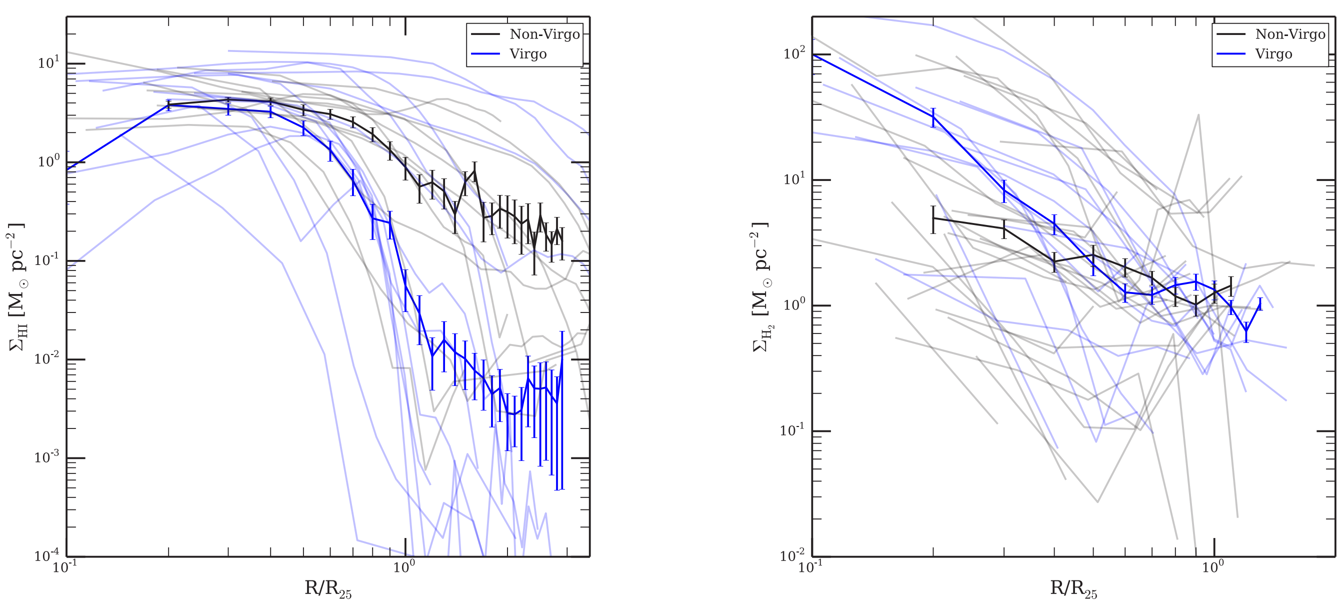



*Figure 20: Left - HI surface density vs. $R/R_{25}$ for our sample of galaxies. The individual galaxy profiles are presented in light blue (Virgo) and grey (non-Virgo). The dark blue and black represent the average value for the Virgo and non-Virgo sample at that radius respectively, along with statistical error bars. Right - $H_2$ surface density vs. $R/R_{25}$, in the same format as the plot on the left.*

from three main sources. The first is from the VIVA survey (Chung & Kim 2014), where we use the provided moment zero maps from their website for 16 galaxies. We also have two VLA programs to observe the HI properties of 14 NGLS galaxies, AW701 and 15B-111. Finally, there is one galaxy, NGC3077, where we use data from the THINGS survey (Walter et al. 2008).

We use the co-ordinates and position angle data from the HyperLeda database (Paturel et al. 2003; Makarov et al. 2014) to generate 20 concentric annuli regions, at semi-minor axis intervals of 15''. For galaxy pairs where data were collected in one map, such as NGC4298/NGC4302 and NGC4567/NGC4568, the other galaxy was masked out manually. We also correct for the effects of inclination. We then normalize the calculated radius by their $R_{25}$ values and calculate the average values at each normalized radius for the galaxies in our sample. These results are presented in Figure 20, where we plot the radial profiles of the HI and $H_2$ distributions for our sample, divided between Virgo and non-Virgo galaxies.

We find that there is a significant reduction in the size of the HI disk of the Virgo sample compared to the non-Virgo sample. This matches the results from integrated measurements of these galaxies (Mok et al. 2016) and previous studies of cluster galaxies. On the other hand, the $H_2$ disks do not appear to be truncated for Virgo galaxies and their surface densities may even be enhanced near the centre. This suggests that the environment affects the dense molecular gas in a different manner than the more diffuse atomic component. In the future, we hope to include resolved Hα maps in this analysis, calculate star formation efficiencies, and perform a pixel by pixel analysis of our dataset.

# Europa and Enceladus with the JCMT

Emily Drabek-Maunder

Within the past decade, discoveries about icy moons orbiting nearby planets have sparked exciting possibilities for life in the outer Solar System, including Europa and Enceladus, moons of Jupiter and Saturn respectively. Both moons have been observed spewing plumes of water into space, similar to the geysers we see on Earth. Their subsurface oceans are likely the origins of these plumes, where water escapes through cracks in their icy surfaces. These oceans could potentially harbour the delicate conditions required for life to develop.

Our project on the James Clerk Maxwell Telescope (JCMT) aims to understand the rich chemistry ongoing in both Europa and Enceladus by observing the outgassing plumes. Past studies of Enceladus have involved the Cassini spacecraft, in orbit around Saturn since 2004, and measured the plumes directly. These measurements have detected vital molecules for life, like water, carbon dioxide, methane and propane. However, Cassini is coming to an end in the next couple of years and similar space missions to Europa will not begin collecting data for at least another decade. The only way for this work to progress is through remote observations on ground-based telescopes like the JCMT.

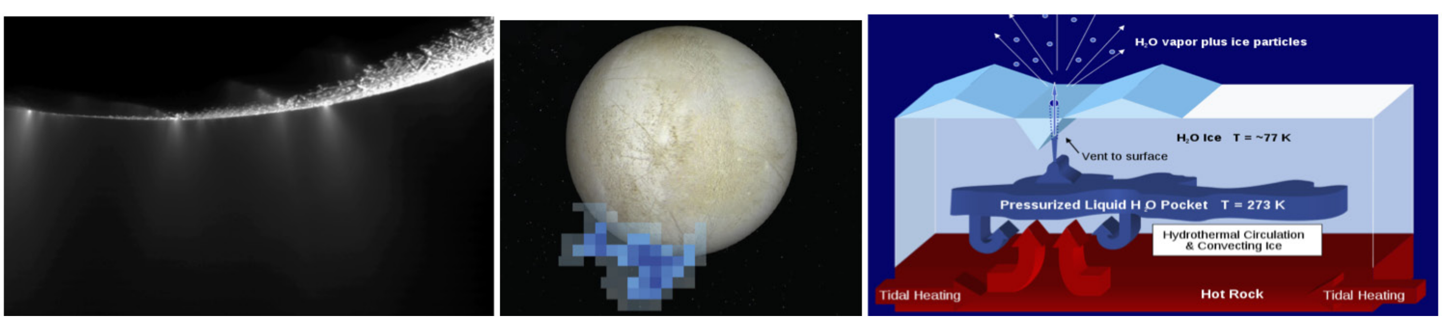



*Figure 21: Below left: Cassini image of Enceladus plumes. Middle: Hubble Space Telescope observations of the detected water vapour plume (blue pixels) overlaid on the disk of Europa (NASA). Right: Diagram of how the plumes are likely produced.*

# Venus Science with the JCMT

Brad Sandor, Todd Clancy and Hideo Sagawa

Since 2000, submm spectroscopic observations with the JCMT have supported altitude-resolved measurements of minor species abundances (CO, SO, $SO_2$, HDO, HCl) as well as temperature and doppler winds in the Venus mesosphere and lower thermosphere (70-110 km altitude). Submm spectroscopy is uniquely suited to this work (indeed is essentially the only ground-based method for observing anything in the altitude range ~75-95 km).

Altitude variation of each observable is retrieved from shape of the pressure broadened absorptions, and is quite sensitive due to the exponential variation of pressure with altitude. Observations at different Venus phases correspond to observations at different local times, supporting studies of local time (diurnal) variation. Studies of secular (non-diurnal) time variation are supported by observations at a single phase, elucidating both very rapid variation over 2-3 week periods during which phase change is negligible, and longer term variation based upon observations separated by 19 month intervals - the period over which Venus' sub-Earth local time varies by 24 hours. Studies of spatial (latitude, local time) variation are supported when Venus (the diameter of which varies from 10" to 60" at superior and inferior conjunctions, respectively) is signficantly larger than the telescope beam (20", 14" and 8" at A-, B-, and D-band frequencies, respectively).

The JCMT has supported many fundamental discoveries about the Venus atmosphere, including:

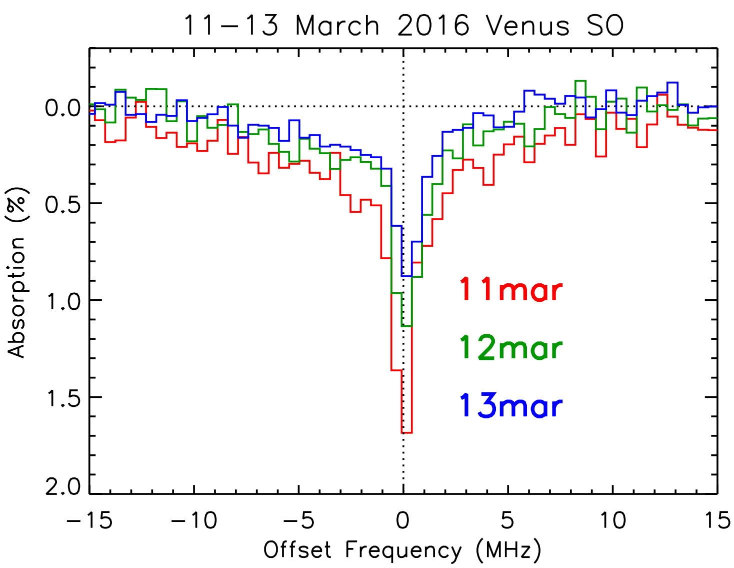



*Figure 22: shows SO abundance changed by a factor of two over the entire Venus dayside, in only 48 hours, from roughly 16 ppb (parts per billion) on 11 Mar, to 12 ppb on 12 Mar, to 8 ppb on 13 March, 2016. These (semester 16A) data provide the first real measurement of the rate of such global changes – SO decreased from 16 to 8 ppb gradually over 48 hours. Observations 5, 6, and 7 days later (not shown) indicated SO abundance was stable at 8 ppb.*

1) SO and $SO_2$ abundances (mixing ratios) each increase with altitude over 70-100 km - the opposite of prior model prediction they would be altitude decreasing.

2) A photochemical mechanism (theory) subsequently proposed to explain the SO, $SO_2$ altitude variation was shown to be incompatible with a strict (JCMT) observational upper limit for $H_2SO_4$ abundances.

3) SO and $SO_2$ each undergo strong (factor of 20) temporal variations that were not predicted and remain unexplained. Variations exhibit diurnal influence, but not control: The sum [SO + $SO_2$] varies widely, and is diurnally independent. However, the ratio [SO]/[SO 2 ] is bimodal, always <0.05 at night and ~0.8 during the day.

4) HCl abundance decreases rapidly above 80 km, contrary to model expectation that it would be the primary Cl reservoir below 110 km. Further, it too was found to vary strongly and rapidly (in 1 month) with time.

5) Observed spatial patterns of nightside temperature and CO change profoundly between consecutive inferior conjunctions.

6) At most times, nightside doppler winds at 100-110 km are predominantly zonal (West to East), with a significant (smaller) Sub-Solar to AntiSolar (SSAS) component. In a small number of cases this is reversed, with SSAS-dominated flow.

7) Nightside hemispheric winds can change between zonal and SSAS dominance on a 1-week timescale.

8) Venus solar transit data characterize the transitions between dayside/nightside atmospheric circulation. JCMT Venus observations continue to be incredibly important. Many observing

runs, over multiple 19-month diurnal cycles were required before the seemingly random SO, $SO_2$ time variation was sufficiently time-sampled to determine the diurnal character of the $[SO]/[SO_2]$ ratio. Sulfur and water compounds are known to react chemically. Two competing theories about Venus photochemistry hold (respectively) that time variations of $[SO+SO_2]$ and HDO should be either positively or negatively correlated. One of our (many) current goals is to obtain sufficient time sampling of $[SO+SO_2]$ and HDO to observationally distinguish between these theories, and to look for any other, more complicated behavior. JCMT observations have revealed the Venus atmosphere to be far more complicated than previously imagined.

# EAO at the IAU, Hawai'i, 2015

Harriet Parsons, JCMT Support Scientist

The timing and placement of the General Assembly of the International Astronomical Union in August in Honolulu, Hawai'i was a fantastic opportunity for EAO to raise its profile on the international stage. At the Opening Ceremony, our Director Paul Ho, outlined the vision of EAO and what our future might hold.

As an exhibitor at the IAU the EAO staff were well placed to answer questions from interested astronomers who were just becoming familiar with our new organization.

The location of the IAU allowed a mixture of EAO staff to benefit from attending such a large conference. Staff from science, instrumentation, computing and operations participated. Callie – our telescope operator – expanded her skill set even further by working in the IAU press office.

Alongside the EAO exhibition space the EAO hosted a "splinter meeting" – a chance for new and experienced JCMT users to come together to share their results and plans. This concluded with an open panel discussion on future instrumentation directions to keep the JCMT at the cutting edge of submillimetre science.

When asked about the conference Paul Ho replied: "*The IAU provided a great opportunity to connect with our emerging community of users around the world, which helped to boost the interest and the preparation for doing science with JCMT.* "

Now, almost a year on, it is good to reflect that many of the plans for the future discussed during the splinter session are now underway at the JCMT: The JMCT Large Programs have not only started but made good progress and POL-2 has been commissioned for science and is taking data. The future Instrumentation project has begun and first plans are to be presented at the SPIE conference in Edinburgh later this month.


*Fiure 23: Left: Jessica Dempsey (left) and Sarah Graves (right) at the EAO booth at the IAU, Honolulu, August 2015. Middle and Right : Telescope operators William Montgomerie and Callie Matulonis helping out in the exhibition area.*

James Clerk Maxwell Telescope
East Asian Observatory