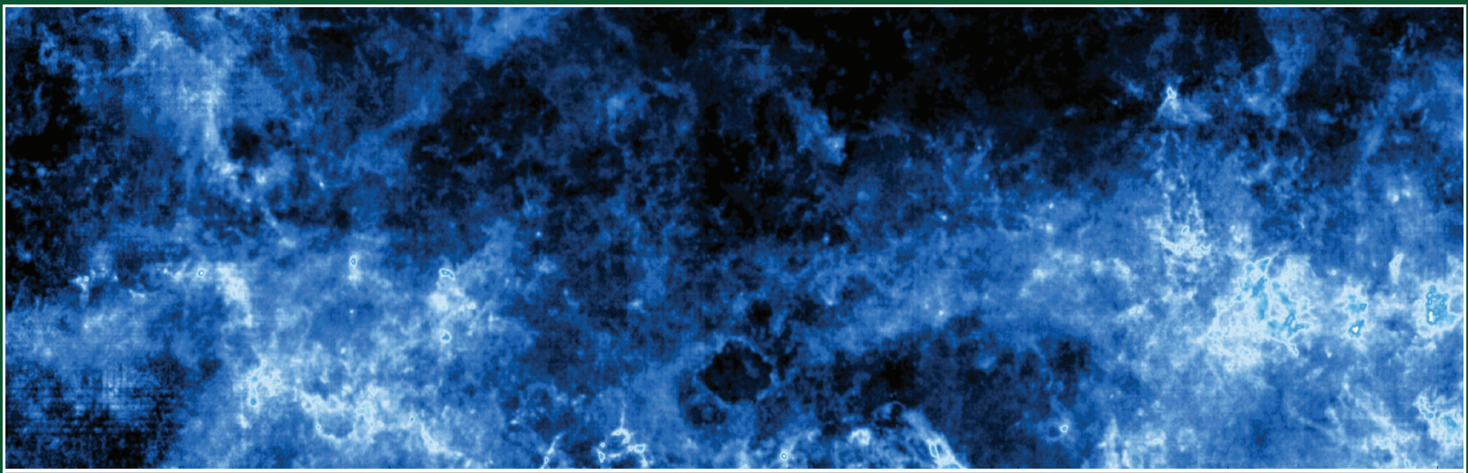
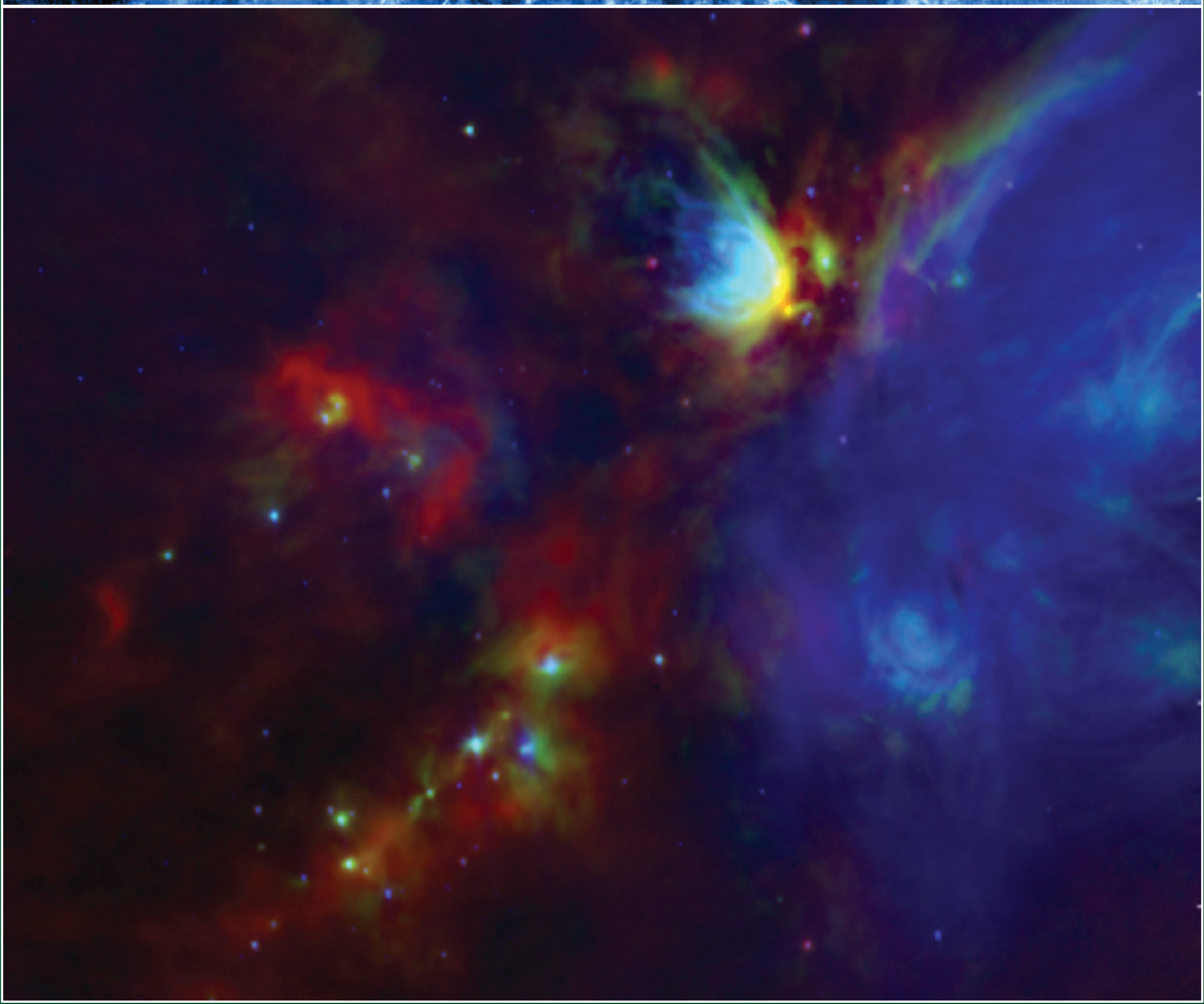
JCMT NEWSLETTER

JAMES CLERK MAXWELL TELESCOPE





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#35 January 2014

JCMT Science

JCMT Science Archive

Observatory News

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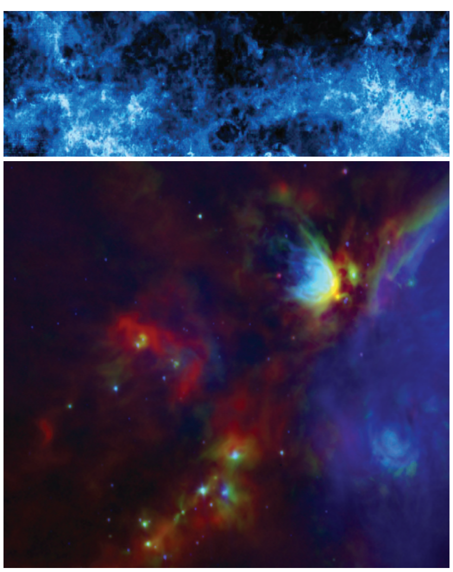
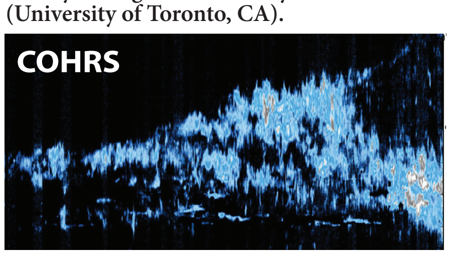


◀ FRONT COVER: (Top) ^{12}CO (3-2) integrated intensity image from COHRS. This region covers l~14°–17°. The COHRS data release is discussed on page 16.
(Bottom) The central, active star-forming region of the nearby L1688 cloud in Ophiuchus in a combined red (SCUBA-2 850 μm), green (Herschel 70 μm), and blue (Spitzer 8 μm) image. The SCUBA-2 data highlight the cold, dense cores where stars are currently forming. The Herschel and Spitzer data reveal young, embedded protostars, and show their heating effects on the nearby gas and dust. The SCUBA-2 data were observed as part of the JCMT Gould Belt Legacy Survey. Both the Herschel and Spitzer data are from their respective archives. The Herschel data were observed as part of the Herschel Gould Belt Survey. Image was made by Rachel Friesen (University of Toronto, CA).



▶ BACK COVER: l-v map from COHRS: the CO High Resolution Survey. COHRS is mapping the Galactic Plane at ^{12}CO (J=3-2) with HARP on the JCMT. Image taken from Dempsey, Thomas & Currie, 2013, ApJS.

The Joint Astronomy Centre (JAC) is based in Hilo on the Big Island of Hawaii and operates the James Clerk Maxwell Telescope (JCMT) on the summit of Mauna Kea. With its clear, dark skies, Mauna Kea is a world-class site for astronomy and the JCMT sits at an altitude of 4092 metres, putting it above much of the water vapour in the atmosphere. With a 15 metre dish, the JCMT is the largest single-dish telescope in the world designed specifically to operate at submillimetre wavelengths.

The JCMT is supported by the United Kingdom's Science and Technology Facilities Council (STFC) and the National Research Council Canada (NRC). It is overseen by the JCMT Board.

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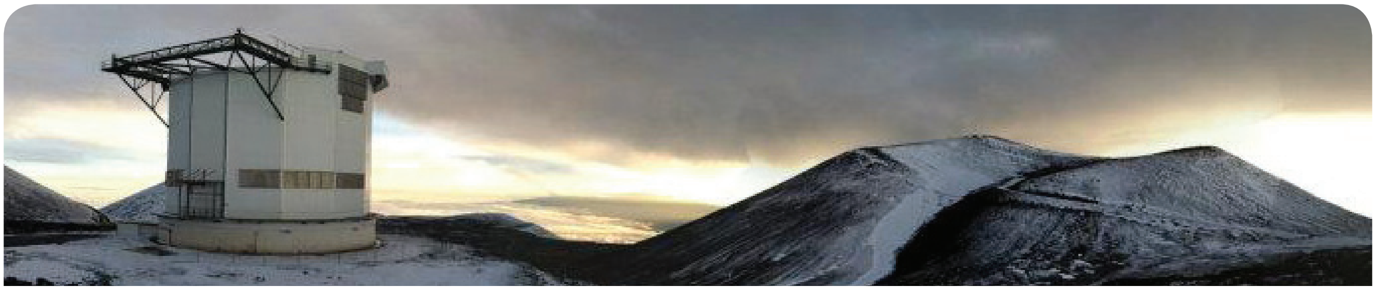
The JCMT Newsletter, James Clerk Maxwell Telescope, is designed and edited by Holly Thomas.

From the Desk of the Director



Professor Gary Davis, Director JAC

Welcome to this edition of the JCMT Newsletter. In the following pages you will find a range of science articles and some updates on telescope operations, demonstrating that the JCMT is continuing not only to produce forefront astronomical science but also to deliver data products of the highest possible quality to our users and to the astronomical community at large. We have a clear directive from the Board to extract the most possible science from the observatory during the time that remains under the current ownership, and to meet that directive we have developed a new operating mode, Extended Observing. All of these developments are described in the Associate Director's column and following pages, so in this article I will dwell only on the process for transferring the observatory to new ownership.

I wrote in the previous Newsletter that the Netherlands funding agency NWO had decided to withdraw from the JCMT partnership on 31st March 2013. This they duly did, and I would like to personally record my thanks to The Netherlands for their financial, technical, scientific and personnel contributions to the JCMT over more than 25 years. The JCMT has unquestionably been a stronger and more successful telescope over this period because of The Netherlands' participation. The last Dutch observing run took place earlier that same month, and in his end-of-run report Frank Israel wrote the following:

It is with sadness and resignation that I write down these last words: the JCMT and its personnel have served the Dutch astronomical community and more in general Dutch science very well over the last quarter century. The telescope and your excellent support has enabled us to reach and maintain a position in the foremost ranks of world astronomy. Thank you for this!

As a consequence of this withdrawal, the JCMT is now a UK–Canada telescope. The UK has increased its financial contribution to compensate, and PI time is now split between these two countries in the ratio 75:25. This reduced partnership will in turn come to an end on 30th September 2014, as discussed in the previous Newsletter. We are now fully engaged in the process of transferring the observatory to new ownership, following the very successful precedent that has already been set for UKIRT. In June 2013 I issued a global Announcement of Opportunity soliciting interest in taking over the operation of the JCMT, and in response I received four Expressions of Interest: one each from the UK and Canadian communities, one from Purple Mountain Observatory, and one from the East Asian Core Observatories Association, a loose affiliation between astronomy funding agencies and institutions in Taiwan, China, South Korea and Japan. From my perspective as Director, it is particularly gratifying that our users in the UK and Canada value their access to the JCMT and wish to remain active participants in the observatory. We must be doing something right! There are initiatives in both countries to submit applications for operating funds, led respectively by Walter Gear (Cardiff) and Mike Fich (Waterloo).

Frank Israel and Jan Wouterloot (TSS) in the JCMT control room on 10th March 2013, during the last Netherlands observing run on the telescope.

These four parties, along with the JAC and the University of Hawaii, which will take over the legal ownership of the facility, met for a workshop in Vancouver on 20th December 2013. All parties agreed to move forward, and although discussions are still at a very early stage I am very optimistic that a new partnership will emerge to take over the operation of the JCMT. I will post updates on the JAC and JCMT home pages as appropriate, so please keep an eye out for the latest news. This is, to my knowledge, an unprecedented process: other than UKIRT, I cannot think of another observatory that has been transferred to new ownership at the peak of its productivity. Moreover, there is much that must happen over the next several months for this transfer to be successful. It is now my primary objective as Director, in the time that remains, to ensure that the legal transfer of the observatory and the transition to operation under new management are both successful, providing the JCMT staff and the new partners, whoever they may be, with the opportunity to continue producing world-leading science for several years to come.

Participants in the JCMT Transfer Workshop held in Vancouver on 20th December 2013. Back row: Jessica Dempsey (JAC), the Director (JAC), Mike Fich (Waterloo), Chris Wilson (McMaster), Doug Johnstone (JAC), Walter Gear (Cardiff), Andrew Blain (Leicester). Front row: Len Cowie (UH), Jonathan Williams (UH), Yu Gao (Purple Mountain Observatory), Jongsoo Kim (Korean Astronomy and Space Science Institute), Paul Ho (Academia Sinica Institute for Astronomy and Astrophysics).

From the Associate Director

Doug Johnstone (Associate Director JCMT)

Aloha once again from the Joint Astronomy Centre in Hilo. I have now had the pleasure of witnessing an entire year's worth of tropical seasons and I am becoming much better aware of the subtle changes to sunset and sunrise. During the summer months there is often enough daylight left at the end of the working day for a quick dip in the ocean. And, in winter, I can now understand the Hawaiian aversion to 'cold' mornings!

The start of 2014 leaves the JCMT with nine months of operations under the current arrangement. In his Director's Comments, Gary has detailed the efforts under way to secure a bright future for the JCMT post-September. There are clearly reasons to be optimistic about the future; nevertheless, there remains a great deal of work to be done at the JAC and an ever shortening period in which to accomplish these tasks. Despite the time squeeze and the general uncertainty, the personnel at the JAC continue to provide exceptional support for the JCMT, from instrumentation through observer support, all the way to data reduction and analysis.

During 2013 the fraction of observing time lost to faults at the telescope was less than 4%, a remarkable feat when one considers the complex and cantankerous nature of our suite of instruments. Furthermore, we continue to seek ways to wring every possible observing opportunity out of the telescope. An Extended Observing regime has been implemented, whereby the JCMT is run remotely from the JAC for a few hours in the morning (see Newsletter article); and staff have inspired changes to the way in which SCUBA-2 is set up and calibrated, yielding additional project time per night.

Unfortunately, the two ancillary instruments for SCUBA-2, the polarimeter (POL-2) and the Fourier Transform Spectrometer (FTS-2), were unable to reach a final commissioned state in time for the Semester 14A Call for Proposals and thus will not be used by PIs in 2014. Given that both instruments were developed in accordance with SCUBA-2's original design specifications, integrating them with SCUBA-2 as-built has turned out to be a fiendishly difficult technical problem. No showstoppers have been identified, and with more time it should certainly be possible to work through the technical issues. As such, POL-2 and FTS-2 remain on the telescope and commissioning work continues on a best-effort basis.

Looking forward to 2014, staff will continue to be kept very busy. Maintenance is planned for both SCUBA-2 and HARP, and development and testing of pipeline procedures for the automated creation of advanced data products within the JCMT Science Archive (JSA) is required. Oversight of the JCMT Legacy Surveys (JLS) and support for visiting observers will also continue.

Semester 14A begins at the start

of February. This will be an extended eight-month semester and, for the third semester in a row, the entire schedule has already been posted to the web. Observers are encouraged to check out the schedule and plan their visits to the JAC well in advance. The split between JLS science and PI observations, covering both the UK and Canada, has been increased to 75/25 to reflect the continued importance of the JLS (see below) and thus there will be fewer opportunities for individual PI's to visit the JCMT. For those that do come out to observe at the JCMT, please consider stopping by the JAC office in Hilo for a day or two ahead of or after your observing run. We'd love to discuss with you the latest insights into data reduction and analysis and hear from you details about your research. Visitor talks are always appreciated and if there is an obvious scientific connection to the staff at the JAC, I have some funds available to help extend your stay.

2013 was a very good year for JCMT publications, topping the century mark for the third straight year. The breadth of science undertaken with this telescope continues to astonish me. In 2013 the JCMT was used as an interferometer (part of the Event Horizon Telescope), undertook daytime observations of Venus and a variety of comets, and spent countless nights peering within and without the Galaxy. The many Newsletter science articles assembled here, from JLS updates to PI programmes, provide only a small glimpse at the output from the JCMT and I urge you to browse the publication list linked from the JCMT homepage. In particular, the record 18 SCUBA-2 publications in 2013 are worth careful consideration.

The flagship science programme at the JCMT remains the JLS, and the efforts undertaken to implement Extended Observing and increase the observing efficiencies reflect concerns around completion of the six individual surveys. A milestone was reached in December 2013 when the JLS passed 50% completion (by time) and, weather permitting, we are now anticipating a final survey completion of better than 80%. As the Newsletter articles and journal papers attest, the scientific rationale for the JLS remains extremely strong. To attain a proper legacy, however, requires not only completion of the surveys but also an effective archive to house the data when it becomes public. To this end, staff at the JAC are working extremely hard to put in place an effective archive, the JSA, to curate both raw JCMT data and advanced products, including source catalogues. Three articles in this Newsletter describe aspects of the JSA and we welcome additional feedback from the community.

The above successes, both in telescope operation and scientific output, suggest that the future of the JCMT should be extremely bright. Indeed, at the various society meetings and science conferences that I attended last year the overwhelming question that I was asked was how to keep the telescope open well into the future. Like Gary, I remain quite optimistic that a path forward to a new operations model will be found. I had the honoured opportunity to speak on behalf of the JCMT at the 2013 East Asian Meeting on Astronomy in Taiwan in October and came away very enthused by the level of interest in our telescope and the awareness of the excellence of the JCMT staff within the larger international community. All this bodes well for the future. In the meantime, there is still much work to be done, and I look forward to supporting the JCMT through the next nine months. And, perhaps, getting in a few more evening swims next summer.

JAC staff photo (September 2013).

S2CLS: Ultraluminous Star-Forming Galaxies in a z= 1.62 cluster

Ian Smail (Durham University, UK) on behalf of the S2CLS consortium

The stars which make up the most massive elliptical galaxies lying in rich clusters today are metal-rich, old and surprisingly uniform, with luminosity-weighted ages of ~8–11 Gyrs and a relatively narrow spread in age at a fixed luminosity and environment (e.g. Smith et al. 2012).

One of the big questions in astronomy is, "can we see evidence for the formation of this population in overdense regions at high redshifts, which subsequently collapse and evolve into clusters today?"

To address this issue we have exploited the large area coverage of the SCUBA-2 Cosmology Legacy Survey (S2CLS) to investigate the properties of luminous far-infrared sources within large-scale structure at high redshifts (Smail et al. 2014). These strongly star-forming galaxies are dusty and hence metal-rich, with star-formation rates which would allow the bulk of their stellar population to be formed in a short period of time. They are thus good candidates for an early phase in the life of ellipticals.

Cluster Cl0218.3-0510

One of the best-studied high-redshift clusters—Cl0218.3-0510 at z = 1.62 (e.g. Tran et al. 2010)—lies by chance within the S2CLS 850 μm survey field of UKIDSS/UDS. We were therefore able to combine S2CLS's sensitivity to luminous, dust-obscured galaxies with other tracers of active populations to map the distribution of star formation within this structure.

For this comparison we used Herschel/SPIRE data (Swinbank et al. 2014) from observations by the HerMES collaboration (Oliver et al. 2012), Spitzer/MIPS and radio observations (Simpson et al. 2006; Arumugam et al. 2014), a narrow-band [OII] survey of this structure by Tadaki et al. (2012), and a photometric redshift survey of the field from Hartley et al. (2013). Using the MIPS and radio catalogues as priors, Swinbank et al. (2014) deblend the SPIRE maps to provide far-infrared luminosities for these sources.

By then matching these samples to the photometric and [OII] surveys, as well as to the archival spectroscopy,

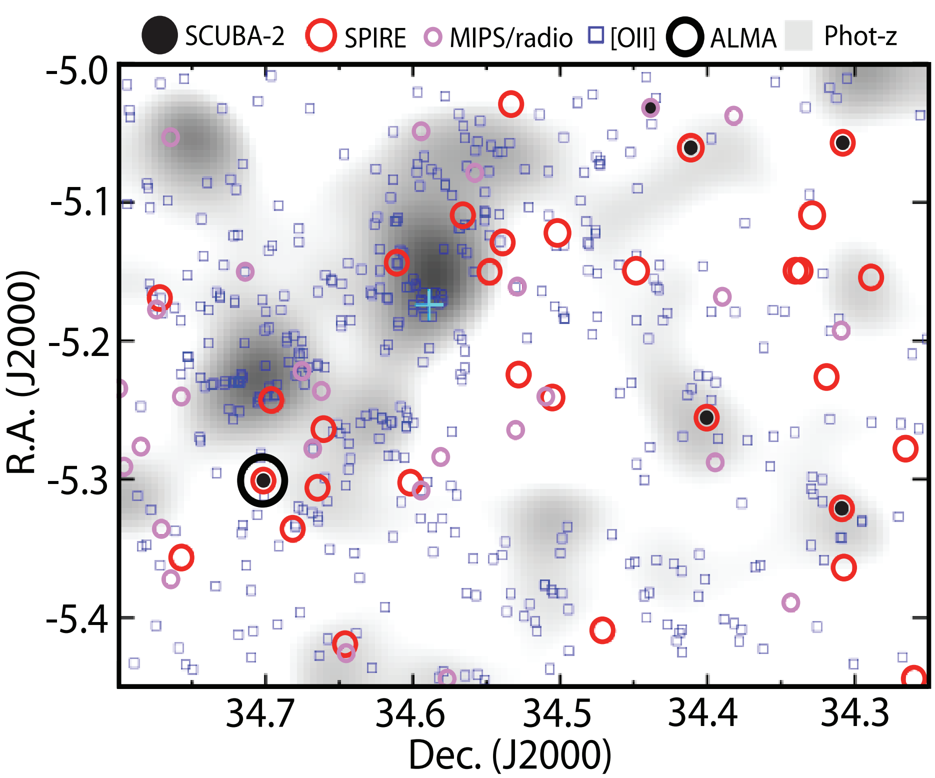


Figure 1: The spatial distribution of galaxy populations in a 0.5°x0.5° field containing the large-scale structure around the z=1.62 cluster Cl0218.3-0510 (marked by the cyan cross) in the UKIDSS/UDS field. We identify the far-infrared luminous members detected by the S2CLS and Herschel/SPIRE sources (all of which are ULIRGs), as well as less-luminous Spitzer/MIPS and radio sources and narrow-band [OII] emitting members from Tadaki et al. (2012). We highlight the candidate SCUBA-2-detected source whose identification as a member has been confirmed by ALMA (Simpson et al. 2014). We see that the ULIRGs are typically found in intermediate density environments within the structure, as opposed to the less-luminous [OII] and colour-selected member populations. We interpret this as indicating that these active members are being accreted onto a pre-existing structure, which is already inhabited by a population of luminous, but passive, galaxies. The background grayscale is the smoothed density distribution (smoothed with a Gaussian kernel of FWHM=1.7 Mpc) of photometrically-identified cluster members from Hartley et al. (2013).

we could identify 31 far-infrared/submillimetre-detected sources which are probable cluster members (Figure 1). These have bolometric luminosities $>10^{12}L_{sun}$ and we show that by virtue of their dust content and activity, they are some of the reddest and brightest galaxies in the cluster.

We also employ Cycle 1 ALMA submillimetre continuum observations of one of these sources to confirm the identification of a SCUBA-2-detected ultraluminous star-forming galaxy in this structure.

Star forming activity

To determine the total level of activity within the cluster we integrate the star-formation activity in the central 2 Mpc region of the cluster and find that it is an order of magnitude higher (in a mass-normalised sense) than clusters at z ~ 0.5–1 (Figure. 2). This demonstrates the significant levels of star formation occurring in the cores of clusters at z > 1.5.

This star forming activity is likely associated with the build-up of the elliptical population which is seen in these regions today (see also the similar recent study of this cluster by Santos et al. 2013). However, we also find that the most active cluster members do not reside in the densest regions of the structure (Figure 1), but are instead found in intermediate density regions. Meanwhile, the higher-density peaks contain a population of passive and massive red galaxies.

The near-infrared luminosities of these active, far-infrared luminous galaxies show them to comprise some of the brightest and reddest galaxies in the optical rest-frame. We find that they have comparable near-infrared absolute magnitudes at z = 1.6, M(H) ~ -23 to the passive galaxies. However, the subsequent stronger fading of the more active galaxies means that, at the present-day, their descendants will be nearly a magnitude fainter than those which evolved from the brighter red galaxies which were already passive at z ~ 1.6.

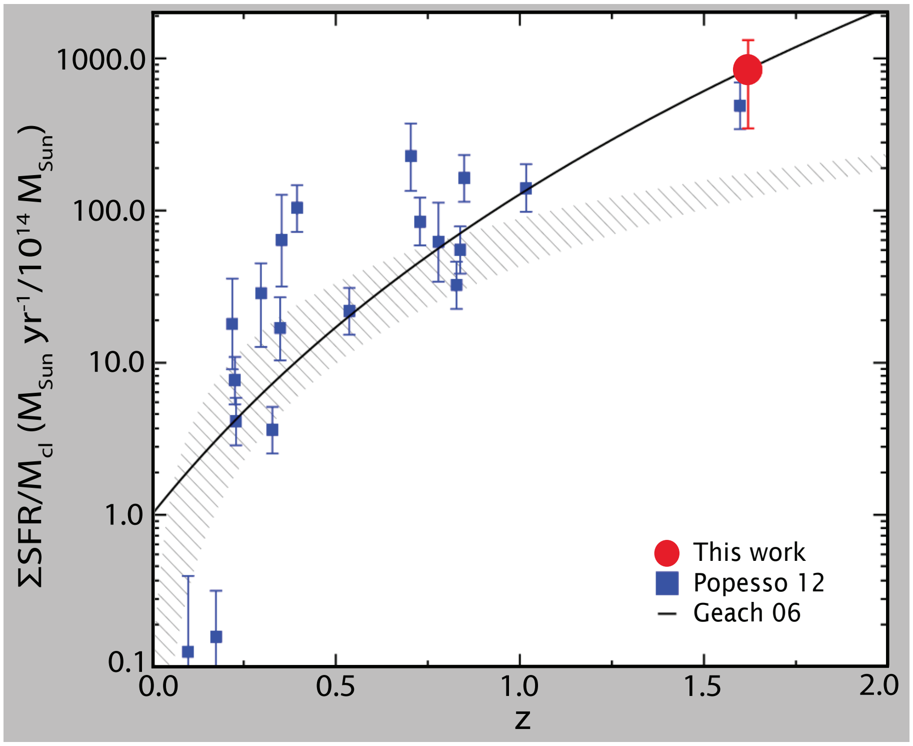


Figure 2: The evolution of the mass-normalised SFR (for galaxies more luminous than $10^{11}L_{sun}$) in clusters and groups as a function of redshift. We plot Cl0218.3-0510 and the data from Popesso et al. (2012). This shows that this z = 1.62 cluster extends the trend for higher mass-normalised SFRs out to the highest redshifts.

The cross-hatched region shows the fitted trend from Popesso et al. (2012) for clusters of galaxies and the solid line shows the $(1+z)^7$ evolution proposed by Geach et al. (2006), based on the field evolution of LIRGs found by Cowie et al. (2004).

We see that the strong evolution implied by the latter model is a better fit to the high-redshift systems than the trend proposed by Popesso et al. (2012) and that Cl0218.3-0510 represents one of the most actively star-forming galaxy clusters known.

It appears therefore that the most massive galaxy population in the dense cores of present-day clusters were already in place at z = 1.6. In Cl0218.3-0510 we are in fact seeing continuing infall of less massive, but still ultraluminous, star-forming galaxies onto this previously built-up cluster core of passive, luminous galaxies.

A rough model for the subsequent evolution of passive and active galaxies in Cl0218.3-0510 matches the H-band luminosity distribution of elliptical galaxies at the present day. If this model is correct, it places the earliest phase of the formation of cluster ellipicals at z ≫ 1.6, possibly extending out to z ~ 5 (Simpson et al. 2014).

Arumugam et al. 2014, in prep.
Cowie et al. 2004, ApJ, 603, L69
Geach et al. 2006, ApJ, 649, 661
Hartley et al. 2013, MNRAS, 431, 3045
Oliver et al. 2012, MNRAS, 424, 1614
Popesso et al. 2012, A&A, 537, 58
Santos et al. 2013, MNRAS, in press (arXiv:1312.1694)
Simpson et al. 2006, MNRAS, 372, 741
Simpson et al. 2014, in press (arXiv:1310:6363)
Smail et al. 2014, ApJ, submitted
Smith et al. 2012, MNRAS, 419, 3167
Swinbank et al. 2014, MNRAS, in press (arXiv:1310.6362)
Tadaki et al. 2012, MNRAS, 423, 2617
Tran et al. 2010, ApJ, 719, L126

JPS: First Results from $l = 30°$

Toby Moore (LJM University, UK) on behalf of the JPS consortium

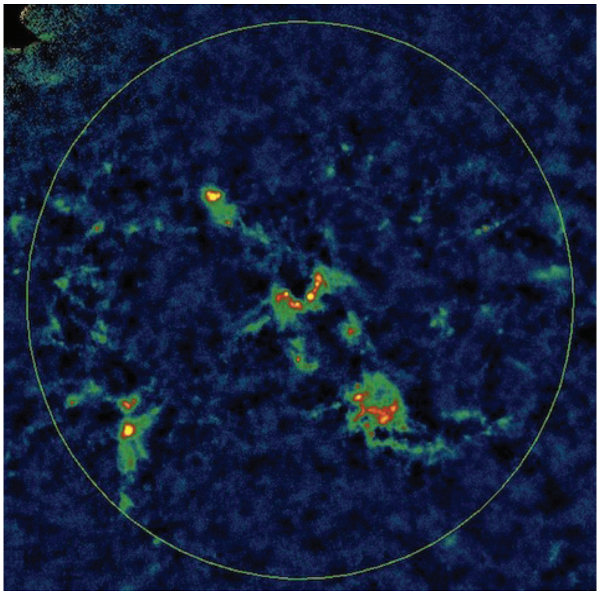


Figure 1: The region centred on W31 at 850 μm and 15” resolution in JPS. A 1° circle is marked for scale. This map was made using a tailored version of the “bright-extended” configuration file for makemap.

The JCMT Plane Survey (JPS) is now around 50 % complete with significant additional progress made since the JCMT Board approved the use of band 4 weather. Since rms values were found to be significantly more stable at tau < 0.15, this limit has been adopted for future observations. This policy has increased the anticipated survey completeness by September 2014 from around 60 % to approximately 80 %.

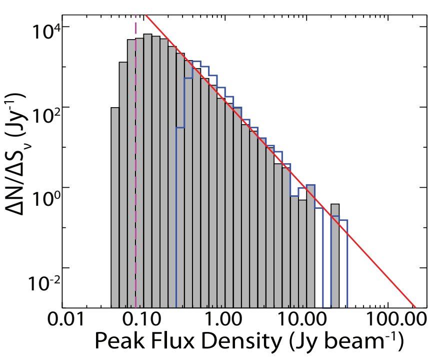


Figure 2: The peak flux density distribution of the compact sources from the JPS l=30° patch (grey histogram). The sources in the same region in the ATLASGAL compact-source catalogue are shown in the open blue histogram. The vertical dashed line shows the ideal completeness limit calculated for a constant Gaussian noise field. The actual completeness limit is likely to be higher than this due to confusion and determines the turnover in the distribution. The solid red line is a power-law fit to the JPS distribution.

Figure 1 shows a sample of JPS data from the inner-most survey region. The map is centred at l = 10.3°, b = -0.13°, near the star-forming region W31. Comparisons of JPS data with the Herschel/SPIRE 500 μm images suggest that no significant compact or filamentary structure is missing from the SCUBA-2 data. The degree-scale background emission found by Herschel is the only significant undetected component in the JPS data. This is consistent with the expectation that only structures larger than ~8 arcmins will be suppressed. Filamentary structures tend to have narrow dimensions smaller than this and survive. A more detailed quantitative determination of the fidelity of JPS data to extended structure will be the subject of a forthcoming paper.

The source-extraction working group within the JPS has completed the first trial extraction of compact objects from a preliminary reduction of the l = 30° patch, which has about half its data observed. After a 7.2” Gaussian smooth, the rms noise in these data is 19 mJy per beam, in 4” pixels. The resulting catalogue contains around 1000 sources with a completeness limit of ~0.1 Jy. The fluxes obtained for these sources compare well to those of ATLASGAL. Figure 2 shows the peak flux distribution of the extracted sources along with that of ATLASGAL sources in the same region of sky. The distributions are very similar except that the JPS data currently probe about a factor of 5 deeper. A preliminary paper describing these results, along with an analysis of the mass distribution in this section of the survey, is in preparation.

Preliminary analysis of the ^{12}CO J = 3–2 line emission contamination of the 850 μm thermal continuum from dust has been done on the same data subset, using data from the COHRS survey in a latitude range $|b| < 0.25$. Initial results are presented in Figure 3, which shows the distribution of the ratio of the corrected flux density per pixel to the original data. This figure can be taken as a probability distribution for the value of the corrected flux relative to the original, with a mode of 98 %, meaning 2 % contamination, and an 87 % probability that the required correction is less than 20 %.

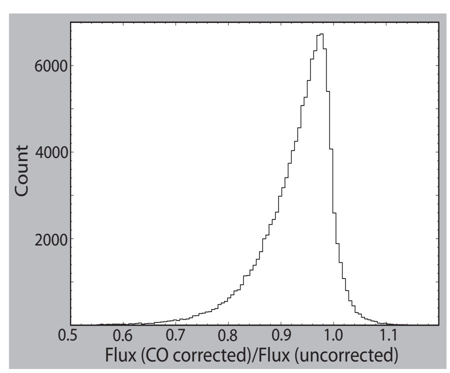


Figure 3: The ratio of CO contamination for pixels above 3-sigma at 850 μm in the l=30° region.

SASSy: Source Finding Begins

Andy Gibb (University of British Columbia, CA) on behalf of the SASSy consortium

Since our last report in the previous newsletter, the SCUBA-2 Ambitious Sky Survey (SASSy) has made excellent progress. To recap, the survey will map of order 700 deg^2 of the outer Galaxy between longitude 120° and 240°, extending to ±2° from the Plane. Each field is 2×2 deg^2, covered by a rotating PONG pattern, with the telescope scanning at 600 arcsec/sec. The primary goal of the project is to detect all the compact sources within the survey bounds above a few times the ~40 mJy noise level.

The survey region is divided into 180 fields, 120 of which have been observed at least once. The median noise level across all mapped fields (after applying the matched filter) is 43 mJy. Figure 1 shows which fields have been mapped to date, and how the survey is fairly complete in the region from 120° to 140°, albeit not to a uniform depth.

The data reduction has its own automated pipeline recipe, plus a handful of PICARD recipes to aid with analysis. Since SASSy's primary goal is identifying compact sources, the reduction is simple and employs a "blank field" config file before running a matched filter on the coadded field maps to highlight compact sources. Data quality is high: the only limiting factor is the atmospheric opacity which determines the sensitivity. The preliminary source finder (using the Fellwalker algorithm in CUPID) has detected 250 sources at 4-sigma or higher. We are currently working on generating a more robust catalogue by experimenting with different source extraction procedures, as well as adding artificial sources to determine the survey completeness. This compact source catalogue will be the primary data product of SASSy.

Part of the original SASSy plan was to use some of the time to conduct short (5-minute) follow up DAISY observations to confirm as many of the detections as possible. So far this has been astoundingly successful, with over 95 % of the 80 or so 4–6 sigma targets being successfully confirmed. Figure 2 plots a handful of examples, all of which were originally 4–6 sigma.

These follow-up observations go about 3–5 times deeper than the original maps, so even a 4-sigma peak will show up at 12–20 sigma. On the other hand, the success of these follow-up observations suggests that our current source finder is perhaps too conservative. Further investigation of the catalogue will allow us to quantify by how much. Given that we're mapping the Galactic Plane, which is full of bright submillimetre sources, we can treat SASSy as a shallow extension of JPS and reduce the data in a similar manner to pick up extended emission. The results are encouraging: Figure 3 shows the W3 region, and demonstrates how SASSy can detect more extended features. *(continued on page 11)*

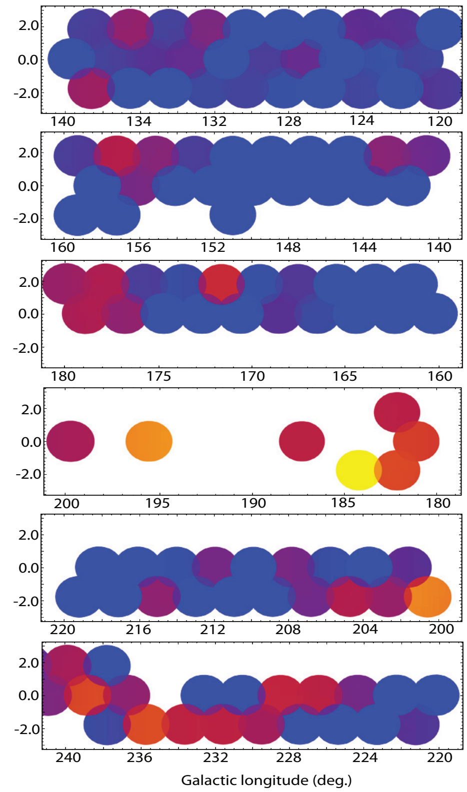


Figure 1: Coverage maps. Each circular field is 2.5° in diameter and colour-coded to represent the median noise (after applying the matched filter). Blue is 40 mJy or lower, yellow is 80 mJy or higher.

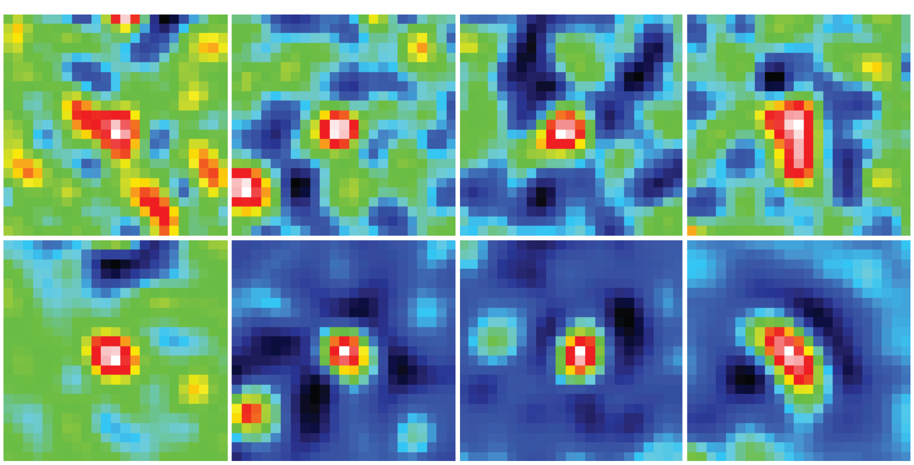


Figure 2: A selection of follow-up observations. (Top row) Original SASSy maps around each 4–6 sigma peak. (Bottom row) Follow-up results which confirms each of those in the top row as real, with peak signal-to-noise ratios of 15–20. The negative dips around the sources in the bottom row is due to the matched filter.

GBS: Filamentary Structures

Carl Salji (University of Cambridge, UK) on behalf of the GBS consortium

Filaments

It has become well known that the process of star formation is strongly tied to molecular clouds and as such it is of great importance to study and understand their structure (Lombardi, Alves & Lada 2010; McKee & Ostriker 2007). Filamentary structure in particular has become an area of great interest as modern submillimetre telescopes have revealed a plethora of complex structure associated with star forming cores and young protostars. However, the unbiased statistical analysis of these structures has been difficult to complete.

Interest in filamentary structure has not been limited to the field of astrophysics. A variety of methods—primarily stemming from the field of medical imaging—to highlight elongated structures have been created.

First studies

To build on previous work, we employ an adaptation of a Hessian-based morphological filter originally used to enhance images of vessel-like structures in the human body (Frangi et al. 1998).

To date, such analysis has been completed on a small sample of nearby star forming regions observed using the Herschel Space Observatory (Arzoumanian et al. 2011). While space-based observing provides many advantages, ground-based observations with SCUBA-2 exceed the Herschel resolution by > 2.5, providing more reliable results for filaments with widths comparable to the Herschel beam size.

Orion A North

Orion A North (also known as the "Integral-shaped filament") is one of the most active and well-studied sites of star formation near to the Sun. Additionally, this region exhibits

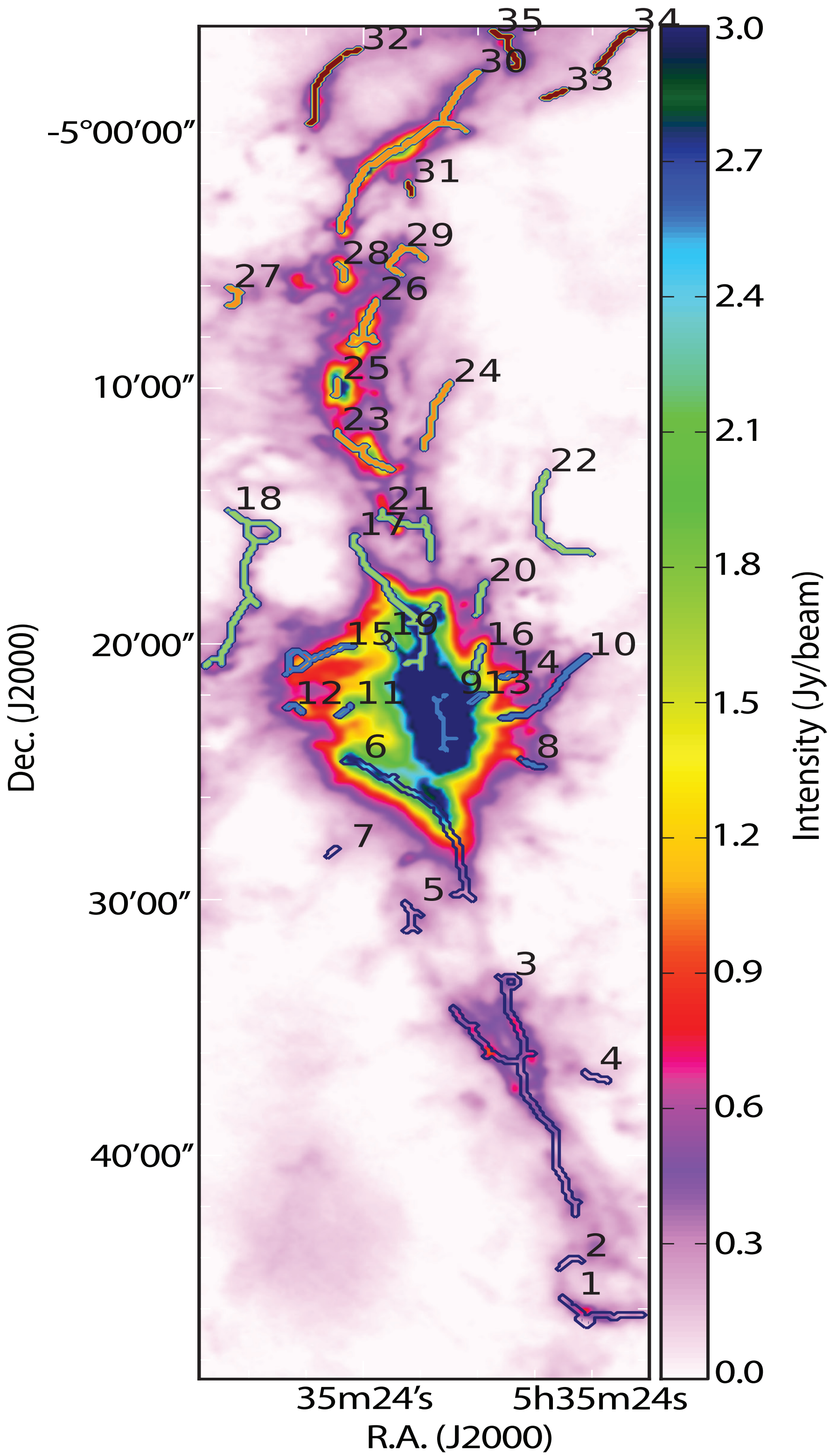


Figure 1: Filaments detected in Orion A North using a Hessian-based algorithm overlaid onto the 850 μm SCUBA 2 image.

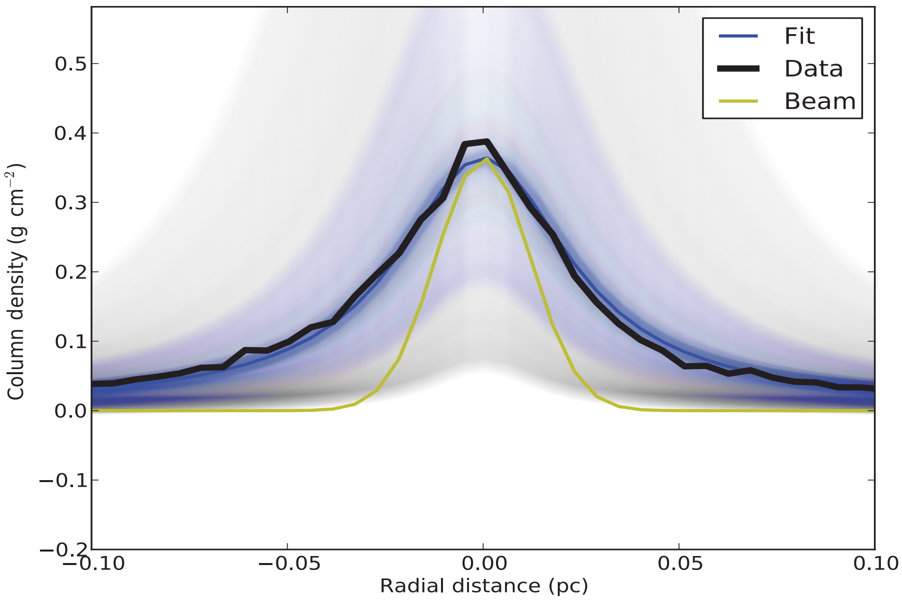


Figure 2: Average cross-sectional profile of filament 30, the Plummer-like profile fits within 1-sigma of the median fit values are plotted, tending towards blue for the optimal fit.

strongly filamentary structure (beautifully depicted in Figure 1—which also demonstrates the algorithmic identification of filamentary structure).

The ratio of the SCUBA-2 filter measurements at 450 μm and 850 μm allows one to derive temperature and column density estimates assuming a modified black-body emission from the dust. However, the uncertainty in column density and temperature derivation is strongly temperature dependent due to the location of the 450 μm and 850 μm measurements relative to the modified black-body emission peak. The temperature determination using these filters is only effective for temperatures < 25 K.

Once the locations of the filament spines have been identified, a variety of analyses can follow. The radial density and temperature profiles of filaments are of particular interest as they can be compared directly to theoretical models that indicate the presence of differing support mechanisms against gravitational collapse.

Preliminary results from the Bayesian-based radial density profile analysis (see Figure 2) suggest that the filaments present in Orion A North are inconsistent with the static, isothermal equilibrium cylinder model, discussed by Ostriker (1964). Ostriker's model approximates a $\rho \propto r^{-4}$ relationship while we observe $\rho \propto r^{-2.5}$ suggesting the presence of additional support mechanisms or deviation from equilibrium and/or isothermality.

One may also investigate the spatial correlation of protostars and their assumed parent filaments. By assuming a relative gas-to-protostar velocity of ~ 1 km s^{-1} (Covey et al. 2006) a star formation rate for each filament may be inferred. Additionally, a lower limit on the age estimate of star formation in Orion A North can be derived by comparing the sum of the individual filament star formation rates and the total number of protostellar sources within the region. A value of 1.1 Myr, which lies in close accordance with previous age estimates of the region, was achieved and strengthens the hypothesis that the majority of star formation occurs in these filaments.

As part of the JCMT Gould Belt Survey, many regions exhibiting strongly filamentary structure have been observed which provide information across a variety of star-forming environments. It is our hope to complete similar analyses on these different datasets to gain a more comprehensive and generalised understanding of the relationship between protostars and their parent filaments.

Arzoumanian et al. 2011, A&A, 529, L6
Frangi et al. 1998, Lecture Notes in Computer Science, V1496, 130-137
Lombardi, Alves, Lada, 2010, A&A, 519, L7
McKee & Ostriker, 2007, ARAA, 45, 565
Ostriker, 1964, ApJ, 140, 1056
Covey et al. 2006, ApJ, 131, 512

(continued from page 9)
Identifications of the SASSy sources with objects in other catalogues will enable the physical properties of the sources to be studied. Of particular interest are those colder objects which do not show up at shorter wavelengths (in IRAS, for example), and hence may represent the early stages of star formation. Additionally, given the transparency of the Galaxy at these wavelengths, it is also possible that some previously unknown sources will turn out to be extragalactic. Although the Planck satellite has made an all-sky catalogue to depths only a bit shallower, the Planck beamsize of 5 arcminutes means that SASSy has the ability to discriminate many new sources right in the Plane, whether Galactic or extragalactic.

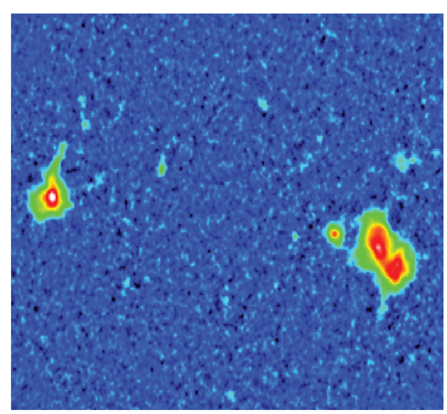


Figure 3: Zoom in of the W3 massive star-forming complex processed to preserve extended emission at 850 μm. The image covers a region 30x20 arcmin^2.

SONS: Weird & Wonderful Disks

Wayne Holland (UK ATC, UK), Brenda Matthews (NRC Herzberg, CA), Jane Greaves (University of St Andrews, UK) & Olja Panić (University of Cambridge, UK) on behalf of the SONS consortium

SONS: a recap of the goals

The SONS survey is measuring the 850 μm emission from 115 nearby stars, tracing the millimetre dust and distribution of planetesimals. All of the stars are known to host debris disks from complementary shorter wavelength observations.

The aims of the survey are to: (1) provide direct dust masses, uniquely constrained at long wavelengths; (2) add points to the far-IR/submm spectrum to constrain the dust size distribution; (3) utilise the power of the JCMT to resolve disk structures around the nearest systems, and (4) look for evidence of resonant clumps and other features in resolved structures that could be indicative of unseen perturbers, such as planets.

Survey progress

As of mid-December 2013 the survey is 85 % complete against the allocation of 270 hours. We have observed 93 of the 115 stars in our sample to a 1-sigma sensitivity level of < 2 mJy beam^{-1} at 850 μm. The survey was allocated equal amounts of time in weather bands 2 and 3, and the band 3 time is now 100 % complete compared to 70 % for band 2.

The DAISY mode continues to be used for the observations; this mapping mode is appropriate for compact sources of less than a few arcminutes in diameter. The data reduction has been refined to adopt the technique of "zero masking" on the AST model (see Chapin et al. 2013) to produce flatter looking images.

The main priority for SONS remains to observe the full sample of 115 stars. Given the amount of time remaining it is likely that the detection rate will stay at the current level of 40 %. A bonus for SONS has been the unexpected high quality of at least some of the data at 450 μm. In some cases structure is even seen at 450 μm and not at the longer primary wavelength of 850 μm. The 450 μm photometry further helps to constrain the spectral energy of the dust, and is proving useful in the interpretation of extended disk structure benefiting from the 7.8 arcsec angular resolution.

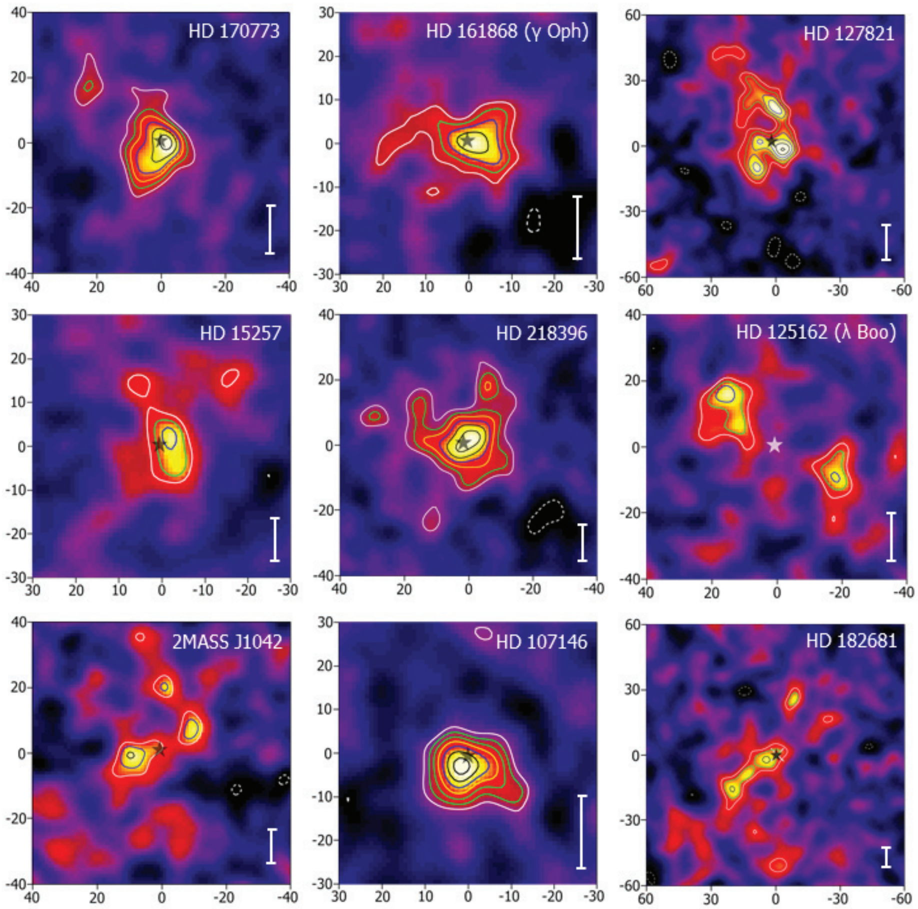


Figure 1: A selection of recent images from the SONS surveys. The contours in each case at -3 (dashed), 3, 4, 5-sigma etc. The bar represents a size scale of 500 AU at the distance of each star.

A gallery of new disks

In the January 2013 JCMT Newsletter we reported on some of our initial results from the first year of the survey. Figure 1 shows that the results from SONS over the last 12 months continue to be spectacular! The range of disk sizes and morphologies is quite staggering. The interpretation of these results is now underway, exploiting the synergy with complementary datasets such as those afforded by the DEBRIS survey using Herschel.

Science highlights

Statistical conclusions, for example, on the fraction of detected disks and their masses, will form the main legacy for SONS. However, a major strength of SONS is that imaging of individual

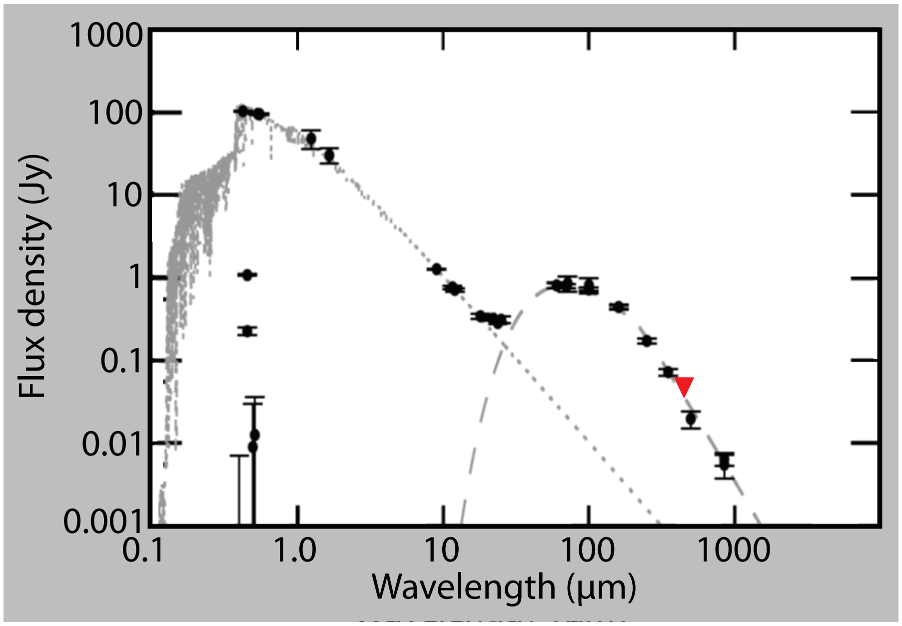


Figure 2: The SED for SONS source HD 14055 from the optical to the millimetre (black filled circles) and the model fits to the photosphere (dotted grey line) and to the IR/subillimetre (dashed grey lines). The red triangle marks the 450 μm upper limit.

or small groups of objects produces publishable results in a relatively small amount of time.

Indeed, this is the case as the first SONS paper describes results from seven newly detected and two previously detected disks at 850 μm (Panić et al. 2013). The disks are characterised via modeling of their spectral energy distributions (SED) to derive dust temperatures which are used to convert the 850 μm fluxes to mass estimates.

Furthermore, submillimetre images greatly assist in the interpretation of disk morphology when combined with complementary data from shorter-wavelengths (e.g. Herschel/PACS). Figure 2 shows the SED for HD 14055 (γ Tri) with model fits to the stellar photosphere and the far-infrared excess. In this a single dust temperature of 76 K is adequate to fit the excess, suggesting the dust is not spread over a wide range of radii in the system.

Figure 3 shows the measured dust masses for circumstellar disks during the pre- and main sequence evolution of low-mass stars (0.2–3.3 M_{sun}) as a function of host star age. These are based on measurements largely from submm/mm detections, including the nine SONS results reported in the Panić paper. It is clear from Figure 3 that in comparison to the disks around pre-main sequence stars the debris disks (~10 Myr and older) are significantly less massive. Meanwhile, the largest measured dust masses for debris disks from 10 to 10,000+ Myr are around $M_{m.s.}(max) = 0.5\ M_{earth}$ (for the assumed dust opacity), irrespective of age. A comparison of evolutionary trends in dust mass is not possible without an unbiased sample, however it remains possible that disk mass remains nearly constant on the main sequence.

One of the aims of SONS is to help to address the issue as to when the transition from the proto-planetary to debris stage occurs and how the disk mass subsequently evolves.

Final thoughts...

The quality of the results from SONS continues to be excellent. Emphasis has now shifted to the interpretation of the results, particularly utilising complementary datasets at different wavelengths. The SONS survey continues to be a major success, more than doubling the number of imaged debris disks at 850 μm.

Chapin et al. 2013, MNRAS, 430, 2545
Panić et al. 2013, MNRAS, 435, 1037

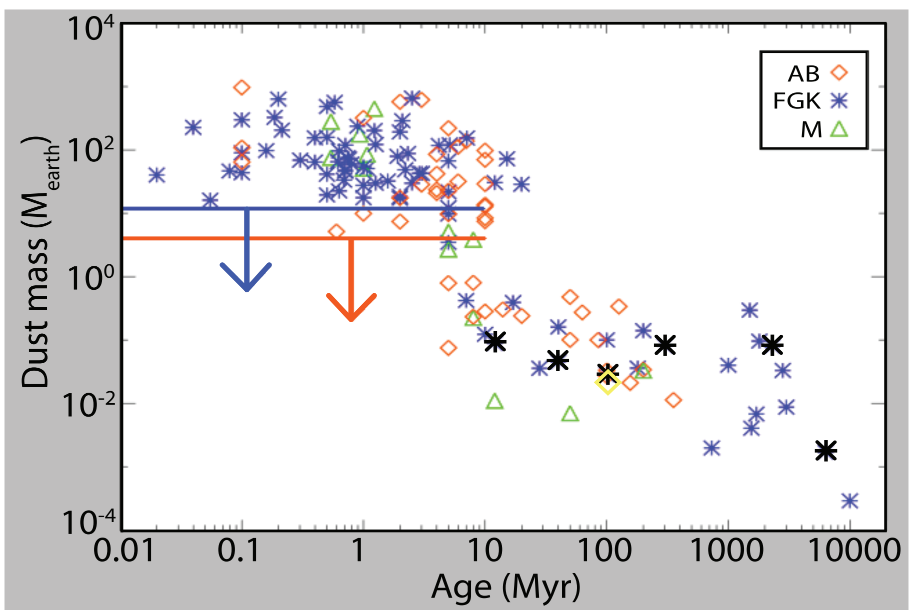


Figure 3: Dust mass evolution of circumstellar disks covering the stellar age range up to 10 billion years. The plot includes nine results from the SONS survey (black and yellow symbols). Observational limits corresponding to a few mJy are shown with arrows: blue for 20 K disks around T Tauri stars and red for 50 K disks around Herbig Ae stars.

Infall Towards Dense Cores

Scott Schnee (NRAO, US)

Starless cores, the pre-cursor structures in which protostars form, are both cold (around 10 K) and dense (typically on the order of 10^5 cm^{-3} or greater). These cores contract due to their self-gravity, resulting in spectral line profiles that, rather than appearing Gaussian, are asymmetric and often dual-peaked. Measurements of asymmetries can therefore be used to measure the rates at which starless cores and the envelopes of protostellar cores are collapsing. We expect the collapse rate to be faster in starless cores on the verge of forming a protostar.

The physical properties of dense cores lead to chemical changes as some molecules freeze onto the surfaces of dust grains and other molecules have their relative abundances in the gas phase enhanced. In particular, the ratio of N_2D^+/N_2H^+ has been predicted to be an especially useful "chemical clock" in starless and protostellar cores, with the value of N_2D^+/N_2H^+ in a core peaking around the same time as the formation of the protostar (e.g. Crapsi et al. 2005; Emprechtinger et al. 2009).

Infalling motions produce a localised density enhancement resulting in these increased levels of deuteration. This is accompanied by a decrease in core temperature due to the additional shielding from the interstellar radiation field. We tested the hypothesis that high values of N_2D^+/N_2H^+ indicate the imminent (or recent) formation of a protostar by correlating deuteration with infall velocity.

We made JCMT RxA observations to measure the HCO^+ (3–2) line with pointings made toward the centers of 26 well-studied starless cores and protostars for which the N_2D^+/N_2H^+ ratio has already been determined (Crapsi et al. 2005). The HCO^+ spectra were fit with a Gaussian model and two infall/outflow models the "two-layer" model from Myers et al. (1996) and the "HILL5" model from De Vries & Myers (2005). The results, presented in Schnee et al. (2013), showed that five cores are expanding, nine cores are static, and eleven are contracting (one core was not detected).

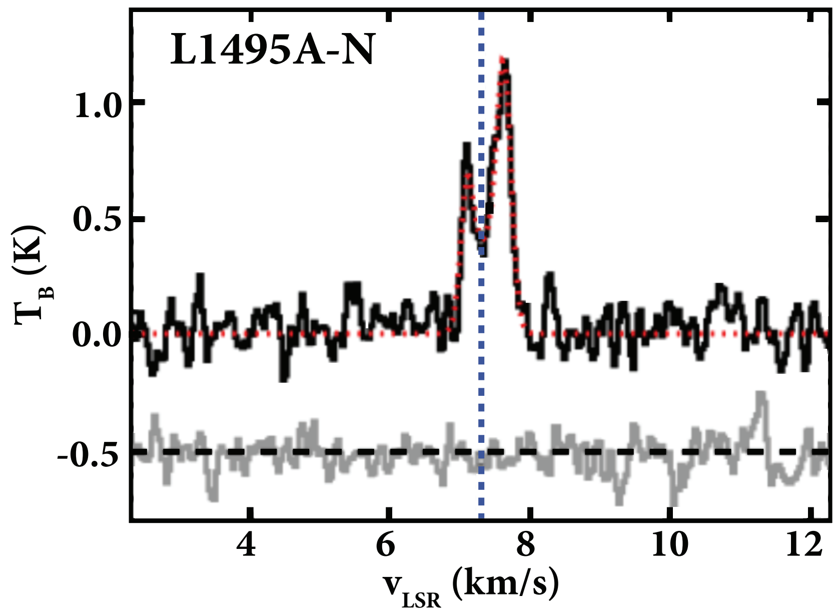


Figure 1: (black) HCO^+ (3–2) spectrum measured with the JCMT RxA towards the protostellar core L1521F. Note the asymmetric profile with the red peak lower than the blue peak, a feature characteristic of self-absorption and inward motions. A fit to this spectrum (red) finds an infall rate of ~0.4 km s^{-1}. (grey) $H^{13}CO^+$ (3–2) spectrum, offset by -0.5 K for display purposes, measured with the JCMT RxA at the same position as the HCO^+ (3–2) line. Note that the $H^{13}CO^+$ line, which is optically thinner than HCO^+, peaks at the LSR velocity of N_2H^+ (1–0) (Crapsi et al. 2005).

Below a N_2D^+/N_2H^+ ratio of 0.1 no correlation with infall velocity was seen. Whilst for the eight cores with $N_2D^+/N_2H^+ > 0.1$ six had infall velocities while two were static. We found a trend of the cores with higher deuteration levels being more likely to show evidence for collapse than cores with less deuteration. This supports the idea that the most chemically evolved starless cores are also dynamically evolved. However, some cores with low levels of deuteration also showed signs of inwards motions. The fastest infall velocity of ~0.4 km s^{-1} was measured towards the young protostar L1521F (see Figure 1).

We also found that cores with $M/M_{Jeans} > 1$ were more likely to have line asymmetries associated with inward, rather than outward or static motions. This supports the result of Simpson et al. (2011) who found that the Jeans stability of a prestellar core may be used as a predictor of its dynamical state.

Crapsi et al. 2005, ApJ, 619, 379
De Vries & Myers, 2005, ApJ, 620, 800
Emprechtinger et al. 2009, A&A, 493, 89
Myers et al. 1996, ApJL, 465, L133
Schnee et al. 2013, ApJ, 777, 121
Simpson et al. 2011, MNRAS, 417, 216

New Insights on Planet Formation

Jonathan Williams (University of Hawaii, US)

The role of SCUBA-2

SCUBA-2 was designed primarily to carry out large scale, sensitive surveys of molecular clouds, nearby galaxies, and high redshift dusty starbursts and this newsletter has documented its success in these areas. But, as with any instrument that provides new opportunities to explore, SCUBA-2 has impacted other fields. In particular, we were able to carry out an innovative study of circumstellar disks in a young stellar cluster. These observations could not have been carried out with any other facility and the data have provided new insights into the formation timescales and diversity of extrasolar planets.

Sigma Orionis

We observed a half-degree diameter circular field toward the sigma Orionis cluster. This region, between the well known Trapezium Cluster and three belt stars (Walter et al. 2008), contains 336 stars that formed together about 3 Myr ago (Hernandez et al. 2007). This is an interesting timescale

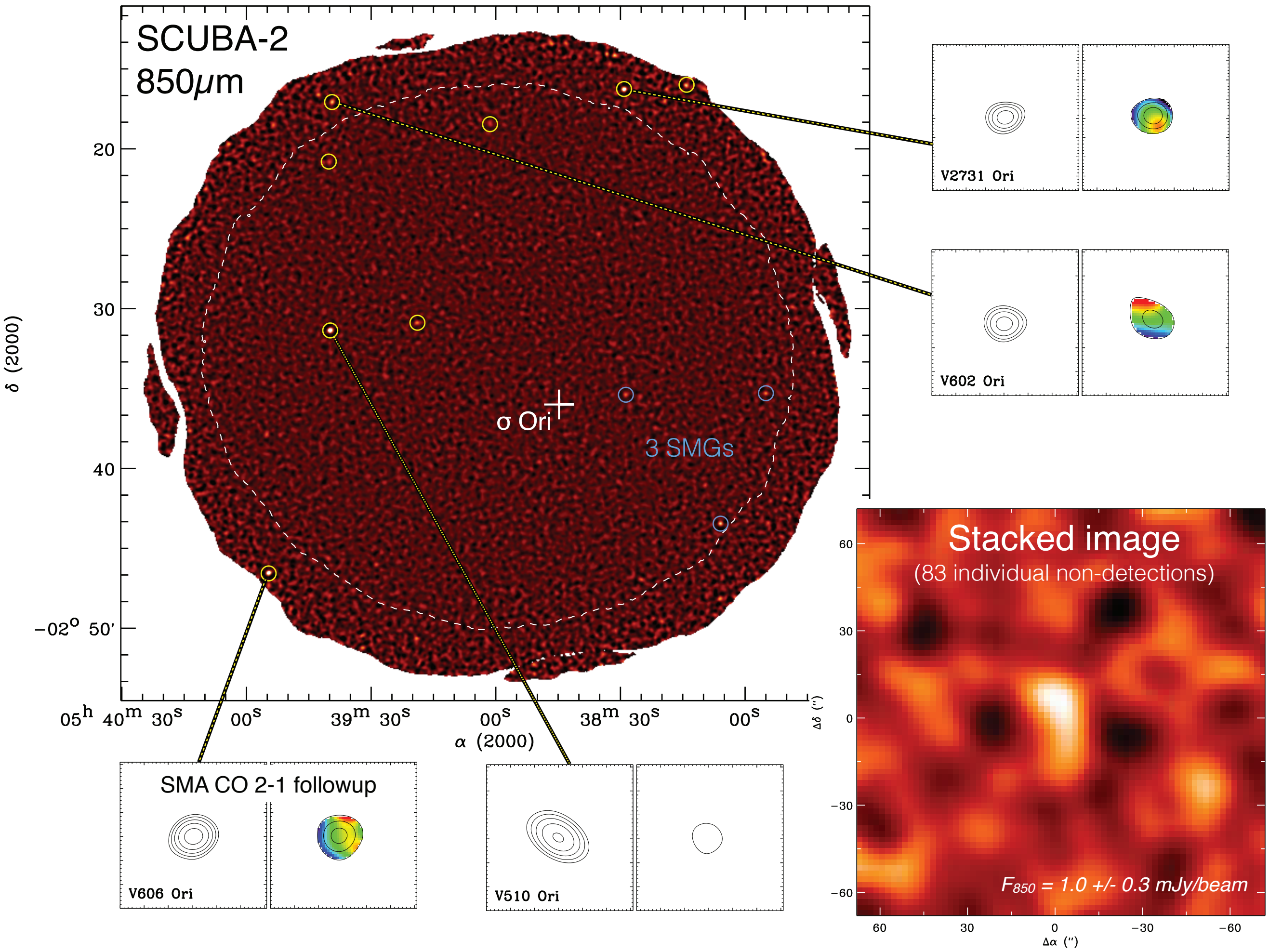


Figure 1: SCUBA-2 observations and follow up of circumstellar disks in the sigma Orionis cluster. The main figure shows the SCUBA-2 map, reduced to show faint point sources. Almost 300 cluster members lie in the field of view, of which 91 show strong infrared excesses from circumstellar disks. The 8 disk detections are outlined by yellow circles. The four two-panel insets show SMA follow up observations that confirm the continuum detection (left panel) and reveal CO 2-1 emission (right panel, colour coded by velocity to show disk rotation) for the brighter sources. These are moderately massive disks, similar to those seen in younger star forming regions such as Taurus, but are the upper tail of the sigma Orionis distribution here.

The stacked map (shifted and coadded) toward the location of the 83 individual non-detections is shown in the lower right corner, and shows a significant mean level of emission. Three additional sources, shown by blue circles, were detected at 5-sigma significance in the SCUBA-2 map but have no optical, infrared, or radio counterpart and are presumed to be background submillimetre galaxies.

as it matches the age of primitive meteorites (Connelley et al. 2012) and theoretical expectations for building gas giants (Pollack et al. 2006).

Another indication that planet formation is well underway is that more than two-thirds of the stars no longer have detectable disks. We wanted to know what was going on in the remaining one-third: how much dust was left and could they continue to form planets?

The final 850 μm map (Figure 1) was about the size of the full moon and contained 91 sources with strong infrared emission indicative of a circumstellar disk. Since very little of the natal molecular cloud remains and the arcsecond-sized disks are much smaller than the beam, the map-making is optimised to look for point sources, akin to deep field searches for submillimetre galaxies*. A notable difference, however, is that the existing optical-infrared catalogues tell us where to look!

The resulting map therefore provides fluxes for all 91 disks at once, which makes it one of the largest submillimetre disk surveys to date, and the largest of such an evolved region. The first impression from Figure 1 is that we did not detect many, in fact only 8, of the 91 disks. But, as with the cosmological deep field surveys, there is much more to it. The implied masses toward the 8 detections are sufficient to form planetary systems on the scale of our own (that is, they exceed the Minimum Mass Solar Nebula), if they have a gas-to-dust ratio of 100 as in the interstellar medium.

Follow-up observations

Follow-up SMA observations of six of the sources confirm the continuum detections and reveal CO emission from molecular gas in four cases (Figure 1 insets). This indicates that the presence of gas and dust are broadly correlated although we cannot determine the gas mass and gas-to-dust ratio from these data.

The infrared SEDs of these eight sources are quite diverse, suggesting a range of disk geometries including several with mid-infrared dips from cleared central holes that may be associated with dynamical clearing by protoplanets (Zhu et al. 2012).

From a stacking analysis, either with the photometry results or by shifting and adding the map (Figure 1 lower-right), we found a significant detection toward the position of the 83 other disks. The inferred mean disk mass is less than half a Jupiter mass, however, effectively ruling out ongoing giant planet formation in these (strong infrared excess) sources. We examined the mean emission toward the 190 cluster members without infrared excesses in the map in the same way and showed that less than an Earth mass in millimetre and smaller sized grains remains around them, a far more stringent limit than any previous measure toward stars of this age.

In short, whereas most circumstellar disks may remain detectable in the infrared for several Myr, these SCUBA-2 observations show that very little raw material remains in the vast majority of them. The implication is that planets—which we know from the various transit and radial velocity surveys to be ubiquitous (Howard 2013)—must begin forming very early on and the growth of planetary cores may be largely over within a couple of Myr after the host star emerges from its core and becomes optically visible.

The results were published in MNRAS (Williams et al. 2013). We are continuing SCUBA-2 disk surveys toward other intermediate aged clusters and pursuing follow-up work to constrain the dust grain size distribution from longer wavelength observations and to measure gas masses from observations of CO isotopologue lines.

Connelley et al. 2012, Science, 338, 651
Hernandez et al. 2007, ApJ, 662, 1067
Howard 2013, Science, 340, 572
Pollack et al. 2006, Icarus, 124, 62
Walter et al. 2008, Handbook of Star Forming Regions, Vol 1.
Williams et al. 2013, MNRAS, 435, 1671
Zhu et al. 2012, ApJ, 755, 6

* Indeed we detect 3 SMGs at 5-sigma significance with $F_{850} > 15$ mJy.

COHRS Data Publicly Available

Holly Thomas (JAC)

Data from the CO High Resolution Survey (COHRS) are now publicly available. They can be found on a dedicated VO Space at the CADC at the following DOI: http://dx.doi.org/10.11570/13.0002.

The survey covers a galactic longitude of 10° < l < 55° with a latitude range between ±0.25° < $|b|$ < ±0.5°. The data were taken at ^{12}CO (J=3–2) with HARP and were reduced using the ORAC-DR pipeline. This project was carried out in a range of sky opacities resulting in non-uniformity of the noise across the tiles. The typical noise achieved is 1 K in 1 km s^{-1} channels.

The data products available on the VO Space are the integrated intensity, longitude-velocity maps and smoothed, reduced cubes (Δv = 1 km s^{-1}). The survey and data products are fully described in Dempsey, Thomas & Currie, 2013, ApJS, 209, 8. More data has been acquired since submission and will be presented in a follow up paper later this year.

Data from COHRS can be seen on the front (integrated-intensity) and back (l-v) covers of this Newsletter.

JCMT Observations of Comet ISON

Iain Coulson (JAC)

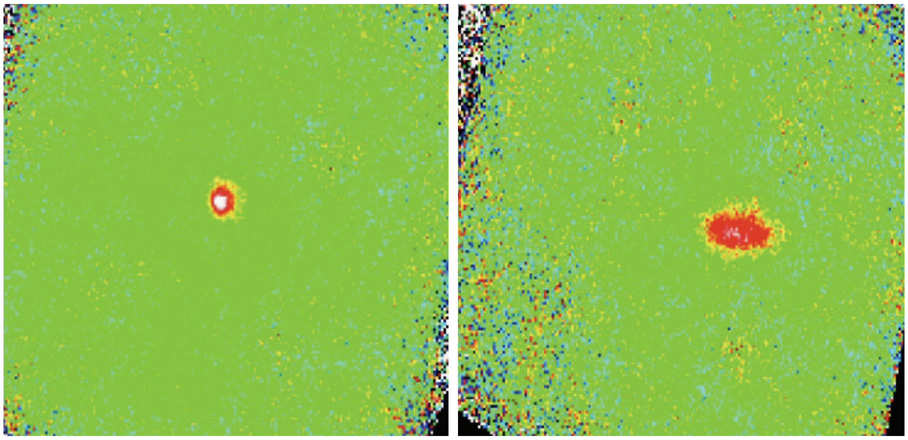


Figure 1: 850 μm images of ISON taken on November 23 (left) & 28 (right) with SCUBA-2 on JCMT. Maximum peak brightness is 130 mJy beam^{-1}.

Comet ISON (C/2012 S1) was widely anticipated by observers of all types. Its close passage of the Sun at the end of November 2013, at a perihelion distance of 0.0125 AU or about 1.3 solar diameters, promised a visual spectacle, particularly post-perihelion, and the early predictions of its outgassing rates promised much to those hoping to obtain chemical inventories of comets. Major observing campaigns were launched a year prior to perihelion, and regular observing with JCMT started in August 2013.

Three groups of observers had been granted access to JCMT: Jacqueline Keane and colleagues from the University of Hawaii; Stefanie Milam and colleagues from NASA, Goddard; and Michal Drahus from Caltech. I was part of Stefanie's team. Our goals were all spectroscopic. The first two groups were hoping to measure emission lines from not just the usual species in the submillimetre spectrum (hydrogen cyanide, carbon monoxide, methanol), but perhaps more exotic species. Anticipating a particularly bright apparition, distinct sub-programmes were approved to measure the usually weak deuterated version of hydrogen cyanide, by which we hoped to answer questions about the origin of Earth's water. Timm Riesen (U. Hawaii) and I led our respective groups on those programs. Michal's goals were to measure the rotation of the ISON nucleus by watching changes in the profiles of high-resolution HCN spectra, and to follow their evolution through the stressful encounter that the comet was scheduled to experience as it rounded the Sun.

On October 5, with ISON at heliocentric (Rh) and geocentric (Δ) distances of 1.6 AU and 2.0 AU, we detected HCN for the first time from JCMT, and reported it via the IAU Central Bureau for Astronomical Telegrams in Electronic Telegram No. 3693. It took three hours to detect the line at a signal-to-noise ratio of about 4! The integrated line strength was 38 mK km s^{-1}, and the implied production rates of HCN and water molecules were about 3×10^{25} s^{-1} and 1.5×10^{28} s^{-1}, respectively. Great comets exceed 10^{31} s^{-1} in the latter characteristic at Δ=1 AU. By mid-November, the HCN line (J = 4–3, 354 GHz) was a lot more impressive and the structure seen in this spectrum was exactly what Michal needed. In anticipation that the comet would release ever-increasing amounts of its interior ices as it approached (and, maybe, survived) perihelion, the deuterium programmes were scheduled during the five days straddling perihelion. Sadly, HCN never got any stronger, the chemistry programmes progressed only haltingly, and the deuterium programmes were never triggered.

Figure 2: Jacqueline, Stefanie and Timm at the JCMT on the day of perihelion.

We started each day of the week of perihelion with a SCUBA-2 image for the purposes of ensuring optimal telescope pointing for the subsequent spectroscopy. Figure 1 shows ISON at 850 μm as it appeared on November 23 and 28, and show its evolution from a fairly condensed object to one a lot more elongated and dispersed.

The 850 μm emission comes from 1mm-sized dust particles; on November 28 these are, on average, displaced from the predicted location of the nucleus by about 45" in the anti-solar direction. This image may be the last of ISON as a coherent solar system body. Attempts were made to image ISON closer to perihelion however we were unable to recover anything coherent. Later images at optical wavelengths (by the SOHO spacecraft) showed dispersing fans and tails (emission from 1 μm-sized particles). The mass of 1mm dust estimated from our images is ~10^{11} kg, or about 1/10th that of the original nuclear mass, assuming a diameter of 1 km. Detailed analyses by all groups are proceeding.

Exciting Science from Space Warps

Jim Geach (University of Hertfordshire, UK)

On Tuesday 7th January 2014, the Stargazing Live programme was broadcast to approximately 3 million viewers in the United Kingdom by the British Broadcasting Corporation (BBC). Running over three consecutive nights, the goal of Stargazing Live is to engage the public with astronomy-related activities ranging from amateur pursuits through to the communication of the latest scientific research, major missions, and projects. The wide reach of this programme makes it a phenomenally successful public engagement tool for promoting astronomy, and indeed science in general.

During Stargazing Live we launched the Space Warps 2 project (spacewarps.org), part of the Zooniverse family of online citizen science projects. The goal of Space Warps is, via a web application, to present (public) users with tens of thousands of images from a large area optical/near-infrared imaging survey (in this case the VISTA-CFHT Stripe 82 survey, of which I am a co-PI) that the user inspects to search for evidence of gravitational lensing. A sophisticated training scheme using realistic images of simulated lenses, built into the experience, is used to educate users on what to look for, and also to calibrate and sanitise the classification process. Humans are far more effective at detecting the—often very subtle—features associated with gravitational lenses, and so harnessing the power of a natural neural network of several tens of thousands of "nodes" is particularly efficient for this task compared to a machine.

The project was phenomenally successful: by the end of the final programme on 9th January, we had logged over 7.5 million classifications of images, meaning that each image in the sample was independently viewed about 200 times. The fact that we presented the user with IJK-band colour composite images means that we were sensitive to "red arcs": lensed galaxies with red optical/near-infrared colours that are traditionally missed by optical lens searches, but could represent old/passive or active/dusty sources at high-redshift.

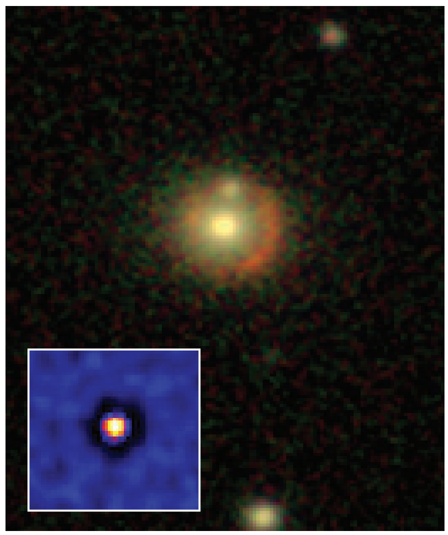


Figure 1: 9io9; a lens candidate identified by Space Warps volunteers. The inset shows the SCUBA-2 detection.

Out of several tens of excellent lens candidates identified by the public, the best candidate we have appears to be an active, dust-obscured source at $z \sim 2$–3. Dubbed "9io9" (from its SpaceWarps identifier), the target appears as a spectacular red Einstein ring, nearly complete in the K_s-band around a luminous red galaxy at $z = 0.202$ (see Figure 1). Immediately on discovery we cross-identified the position with other surveys. The source is detected in the VLA FIRST 1.4 GHz survey, at 4 mJy, and is also an extraordinarily bright submillimetre source: the Herschel Stripe 82 Survey (HerS, Viero et al. 2013), reveals an extremely bright submillimetre source at the position of 9io9 with a 350 μm flux density approaching 1 Jy. This high flux density, characteristic of other lensed submillimetre galaxies (Negrello et al. 2010) indicates a dust obscured, active (starburst or AGN) galaxy.

We obtained 30 minutes of SCUBA-2 DDT observations of 9io9, allowing us to measure the 850 μm flux density (the integration time was too short to provide a robust 450 μm measurement, although the integrated 500 μm flux density has been measured by Herschel/SPIRE). Owing to the lensing, this is one of the brightest high redshift extragalactic sources ever seen by SCUBA-2. The 250–850 μm photometry allows us to model the dust spectrum across the peak of the emission, indicating a source redshift of ~2.5. Even taking the lensing into consideration, 9io9 is an extremely luminous galaxy, with a total infrared luminosity around $10^{13}\,L_{sun}$ putting it in the "hyperluminous" class, and the high radio luminosity of the source suggests that the source contains a luminous AGN: an actively accreting supermassive black hole.

Rare cosmic alignments such as this offer unique insights into the inner workings of galaxies at a time when galaxy formation was at its peak around 8–10 Gyr ago. The flux boosting and angular stretching that lensing provides allows us to examine distant galaxies in far greater detail than would otherwise be possible. SCUBA-2 has provided some of our first basic insights into the properties of the source we are calling 9io9, and will pave the way for more detailed follow up with interferometric and other high-resolution observations. Finding the galaxy in the first place is a real challenge, and this serves as an example of the power of "citizen science" in accelerating this process.

Negrello et al. 2010, Sci, 330, 800
Viero, 2013, AAS, 221,21504

The JCMT Science Archive

Ambitious Plans for the JSA

Doug Johnstone (JAC)

The JCMT Science Archive (JSA) is an ambitious project designed to provide a solution to the challenge posed by increased data rates and volumes, and to support the JCMT Legacy Survey (JLS), which demands the uniform processing of large data sets acquired incrementally and asynchronously over a number of years. The JSA, a collaboration between the JAC and the Canadian Astronomy Data Centre (CADC), will also ensure a lasting legacy for JCMT data well into the future.

At its simplest level, the JSA stores and curates raw data taken with the JCMT. On a nightly schedule, observations are transferred to the CADC and ingested into the JSA, along with ORAC-DR reduced products such as calibrated images (SCUBA-2) and spectral cubes (HARP). These data are available immediately for downloading by PIs and authorised JLS team members. Once the proprietary period has elapsed, all these products, raw and reduced, become accessible by everyone.

To achieve its objectives however, the JSA must also be able to uniformly process large collections of data into images and cubes. This is especially true for the extremely large JLS data sets, taken over an extended period of time. Furthermore, the regions these data cover are often very large, requiring a tiling scheme for optimal map storage and delivery. The JSA has opted to use the HEALPix formalism, which allows tiles to be mosaiced on the sky simply by abutting them in pixel space. Graham Bell discusses this issue in more detail in his article 'Tiling Scheme for the JSA' on the next page.

Beyond maps and cubes, and their associated variance components, the highest priority advanced data product within the JSA remains a catalogue of observed sources of submillimetre emission. Defining such a catalogue, however, can lead to much passionate debate as there are many legitimate and scientifically compelling options for both identifying sources—from point sources to large clumps—and determining the search parameters. Each JLS team is independently wrestling with this question and the expectation is that the surveys will provide the best science catalogues for their respective regions and research goals. Thus, the JSA-wide source catalogue aims to be more generic. Sarah Graves discusses this issue in more detail in 'Source Finding for the JSA' on page 20.

The JSA will be significantly enhanced by the ingestion of user-generated advanced data products, especially those produced uniformly by the individual JLS teams (such as the sources catalogues described above). With limited time and manpower at the JAC, harnessing the efforts of the JCMT community will be necessary to create a lasting legacy. The JAC is working closely with the CADC to determine the most effective and efficient manner in which to bring these products into the archive and make them available to all users. It is worth noting that the CADC already possesses the ability to store static data sets, outside the archive, and to provide a Digital Object Identifier (DOI) for these data, suitable for use in publications (see for example http://dx.doi.org/10.11570/13.0001 or http://dx.doi.org/10.11570/13.0002).

Finally, in order to enhance the legacy of the JCMT, over a decade's worth of heterodyne data taken at the JCMT with the DAS are being translated to allow for pipeline processing using the current suite of ACSIS heterodyne recipes. This endeavour will allow these data, which already reside at the CADC in unreduced format, to be used by astronomers without requiring obsolete software. Once the translations are complete, the JSA will be able to store and curate these historical data sets seamlessly with the more recent HARP and SCUBA-2 data.

The JSA is definitely an ambitious project and both time and manpower are limited. The importance of a well designed and implemented archive, however, can be clearly seen through the continuing high publication count of SCUBA papers many years after the instrument was decommissioned. Already the JSA is working well for the storage and curation of nightly observations. With the enhancements described here, the JSA undoubtedly will be a leading example of how an astronomical archive should work.

Presentations from the SCUBA-2 Data Reduction Workshop (which was held in Manchester, UK, in February 2013) are available on the JAC webpages at:
www.jach.hawaii.edu/JCMT/continuum/workshop-feb2013/
Topics include an overview of SCUBA-2, calibrating your data, and data reduction tips and techniques.

Tiling Scheme for the JSA

Graham Bell (JAC)

Tiled maps and data cubes have long been part of the plan for the JCMT Science Archive, and in the last few months these plans have been taking shape around the HEALPix pixelisation scheme. Hierarchical Equal Area iso-Latitude Pixelisation (HEALPix) (Górski et al. 2005) divides the sky into twelve diamond-shaped facets or "base resolution elements". There are four facets in a ring around the equator and four more in a ring around each pole. The facets are then divided into a 2 × 2 grid of similar smaller diamonds at the first resolution level. This division process continues hierarchically until the desired pixel size is reached.

We have selected a tiling scheme for the JSA where the tiles are defined by suitably sized HEALPix "pixels" and the pixels within them are HEALPix pixels of a higher resolution level. The use of HEALPix for the tiles provides a grid over the whole sky which is fully defined at the start of the process—we do not need to adapt the tile positions to the regions of the sky observed. In addition, HEALPix provides two standard numbering systems, of which we have chosen the "nested" scheme. Because of the way HEALPix is constructed, the tiles can be joined by abutting them and the pixelisation is continuous between them (see Figure 1).

SCUBA-2 maps will be split into ~1° tiles (N_{side}=64), chosen to be a suitable fit for daisy observations, with 3.22" pixels at 850 μm and 1.61" pixels at 450 μm. These are the lowest available HEALPix resolutions giving three pixels per beam width. HARP data cubes are to be ~¼° (N_{side}=256) with 6.44" pixels as a compromise between a reasonable file size (1 GB at the highest spectral resolution) and the number of pixels in the cube (128 × 128). The tiles are stored using the FITS HPX (Calabretta & Roukema, 2007) projection which rotates the HEALPix facets anticlockwise by 45° so that they become squares aligned with the coordinate axes. This, and the fact that the pixels are not quite square, are the less desirable features of the tiling scheme when it comes to viewing the tiled images. Therefore in the next Starlink release, SMURF will include a script "JSAJOIN" for abutting the tiles and resampling them into a tangent-plane projection. However it will also be possible to work with the tiles directly in the HPX projection and any tools with a modern WCS implementation, such as DS9 and GAIA, already support this.

While HEALPix was originally designed for work with CMB maps, it features in emerging Virtual Observatory schemes such as MOC and HiPS. Multi-Order Coverage (MOC) (Fernique et al. 2013) is a computationally convenient way of representing regions of the sky like the footprint of a survey or regions of detected emission as a list of HEALPix pixel numbers. Hierarchical Progressive Survey (HiPS) is used by Aladin for its all-sky browsing mode which loads 512 × 512 tiles at a series of increasing HEALPix resolutions (see Figure 2 on the next page). If these kinds of VO technologies take off then we hope that the JSA tiles will inter-operate well with them, but in either case HEALPix and the HPX projection give us a very convenient way to define the JSA tiling scheme.

Górski et al. 2005, ApJ, 622, 759
Calabretta & Roukema, 2007, MNRAS, 381, 865
Fernique et al. 2013, ASPC, 475, 135

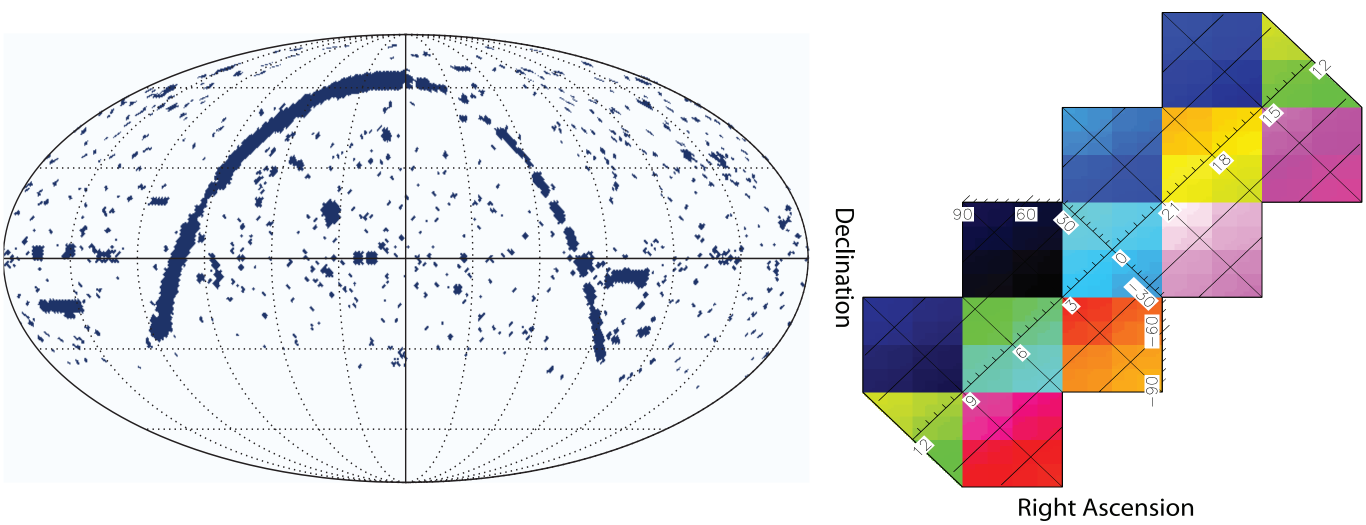


Figure 1: (left) Plot of the SCUBA-2 HEALPix tiles over the whole sky in the Mollweide projection including both JLS and public PI data. (right) Illustration of the HPX projection plane with colours showing the nested pixel numbering scheme.

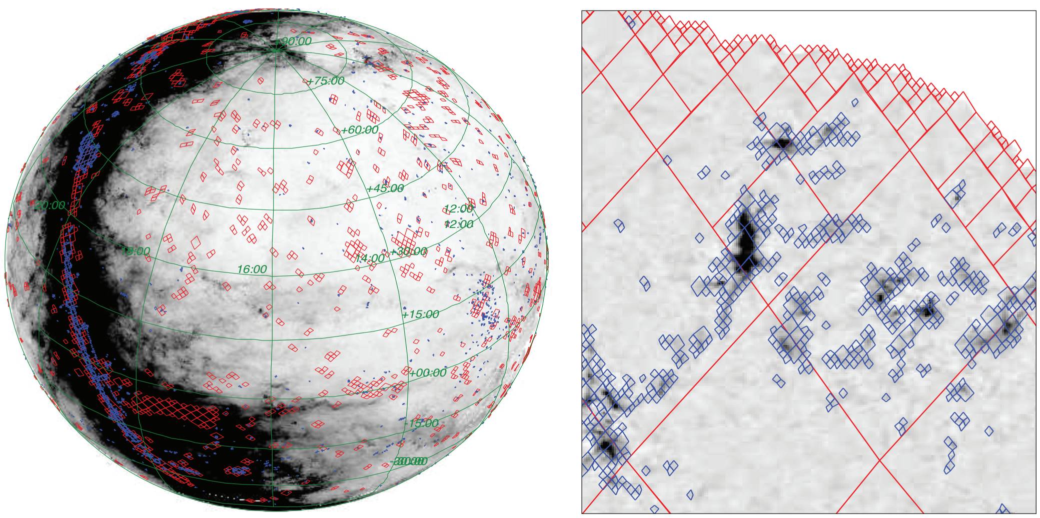


Figure 2: Examples of emerging VO schemes using HEALPix. (left) Aladin all-sky mode showing Planck 857 GHz data overlaid with the footprint of JCMT SCUBA-2 (red) and HARP (blue) observations. (right) SCUBA-2 map of DR 21 with MOC representations of the footprint (red) and emission over 7 sigma (blue).

Source Finding: Creating a Legacy Catalogue

Sarah Graves (JAC)

As part of the JCMT Science Archive, we are planning to produce source catalogues for all JSA tiles. These are not intended to replace or supplant the scientifically motivated catalogues of physical objects being produced by the various JCMT Legacy Surveys and PI teams—instead, we are hoping to supplement these works with an emission-focused, uniform approach. The primary question we hope to be able to answer, in as user-friendly a manner as possible, is: "where did the JCMT detect emission?"

Our current intent is to produce two catalogues for each JSA tile. We will have a first, fundamental catalogue, in which we identify all the detected emission within the tile. We will also have a second catalogue that identifies any localised peaks within this detected emission, and presents some basic quantitative values for these peaks. These will be produced for both SCUBA-2 and heterodyne observations, and will be available to download at the CADC archive. In addition, we hope that users will make use of interfaces such as TAP (being implemented in GAIA) to easily query the JSA from other programmes and perform catalogue matching with their current work.

To identify the basic detected emission, we are planning on applying a conservative limit based on the noise within the maps. The algorithms already available within CUPID will be used to remove spurious detections of objects smaller than the beam and separate out spatially disjointed areas of emission. For the catalogue of peaks, we are using the FellWalker algorithm within CUPID which has shown itself to be robust and reliable at identifying peaks.

While we are developing our plans and implementations of the JSA and its catalogues, we have been trying to keep in mind the uses astronomers might have for these data sets. As one example use for the catalogue we would like to support, imagine you have a large population of sources from a different waveband, and you wish to quickly assemble the subset of them for which there are 850 μm detections. We would like you to be able to determine which of these positions fall within a (conservatively) detected island of emission in the SCUBA-2 850 μm JSA tiles.

As another example, imagine you are sitting at your computer looking at a large Herschel map. We plan that you will be able to open up a window within GAIA and query the JSA from there. GAIA will then show the footprints of the JCMT's publicly available observations and outlines of the detected emission overlain on your image—so you can clearly see where the JCMT has looked, and where emission was detected. If emission is detected you should be able to plot and view some basic information about the structure of this emission from the catalogue of localised peaks.

If you wish to follow up the JCMT data further you will be able to go to the CADC archive and view the relevant JSA tiles, download the catalogues and the (raw and reduced) data, and find out if there are PI or Survey produced data products (including more specialised catalogues) and papers available to you.

Our motivation for this work is to produce a legacy of information on the JCMT-detected emission, available in a format that is useful and easy to use by both the current JCMT users and the wider astronomical community, whether expert in submillimetre observations or not.

Observatory News

The JCMT Goes Remote

Jessica Dempsey (JAC)

So much observing to be done, but so little time! Some creative thinking was needed to allow more time for the completion of the JCMT Legacy Surveys within the time constraints imposed on JCMT operations. The challenge was how to extend our scheduled twelve hours of night time observing. Any proposed plan needed good, stable weather whilst not impacting on daily engineering work, nor breaching our 14-hour-at-summit safety limits and without over-taxing our heroic operators.

The obvious choice was to operate remotely from Hilo, making use of the clear, stable morning hours, from 7am through to the arrival of the JCMT day-crew at around 10am on work days, and to midday on other days. With these extensions we have the potential for an extra 27 hours (more than two extra nights) per week. Extended Operations would be limited to observing only SCUBA-2 JCMT Legacy Survey observations, with the exception of nights assigned to the University of Hawaii.

After the successful transfer of UKIRT to fully remote operations in 2010, the way was paved for a smooth introduction of remote operations at JCMT. The main engineering challenges, both hardware and software, were the need to control the roof and door closure and telescope drive systems remotely. To ensure the safety of both people and equipment a suite of six interior and exterior cameras were installed, including an infrared camera.

The initial hardware and software work was conducted in August and September of 2013, with the first testing of the procedure successfully completed in early October.

A group of support and software staff then volunteered to become our first Extended Operators. From late-October through to December, morning remote Extended Operations were successfully conducted between Monday and Thursday when weather conditions were favourable.

Eldridge Shay and Cameron Wipper get to grips with new software during extended observing from Hilo.

At the start of January we welcomed Cameron Wipper and Eldridge Shay as our new Extended Operators. Full, seven-day-a-week Extended Operations officially began in the third week of January. Unfortunately we were hit by winter storms at the summit but are now back on track.

Feedback from recipients of the first EO data is extremely positive and we expect that this additional observing time will contribute significantly to the final completion of the JLS projects by the end of September 2014.

1000 Citations

Fifteen years ago a new population of galaxies known as 'SCUBA galaxies' were discovered with SCUBA on the JCMT. These galaxies are enshrouded by dust and characterised by bright submillimetre emission. They are the most active star forming galaxies in the Universe.

Their detection was first reported in the 1998 Nature paper by Hughes et al. In October 2013 this iconic paper achieved 1000 citations, an impressive number and one that continues to rise. We are confident that results from SCUBA-2 will prove as useful over the coming decade.

Employee of the Year

Craig Walther was named 2012 RCUH Outstanding Employee of the Year. He received this award for his exceptional work when, following the departure of our Chief Engineer, he stepped into the role of Acting Chief Engineer, in addition to his regular duties as Head of Software and Computing Services. Congratulations to Craig!

Arrivals and Departures

The ever-changing family here at the JAC once again has bid a fond farewell and said a warm welcome to several staff over the past year. In this edition we say our goodbyes to Susan O'Neal, who for many years guided new employees through the complicated world of HR and immigration, and to UKIRT TSSs Thor Wold, who retired after 28 years service, and Jack Ehle, who was the "new kid" for the past 6 years.

We're happy to have a number of new faces gracing our halls: Chris Laude (Chief Engineer); Simeon Johnson and Kevin Loy (ETS); Sam Benigni and Erik Moore (UKIRT TSSs); Bob Dexter (Assets Disposal Coordinator); Sarah Graves (Scientific Computing); Lawrie White (Admin. Assistant) and Eldridge Shay and Cameron Wipper (JCMT Extended Observing Operators).

Outreach Activities

Aliens, AstroDay and Annual Races

Harriet Parsons (JAC)

AstroDay, an astronomy community day held each year in Hilo, proved to be another success story for outreach in 2013. Children of all ages came to the JAC's "Create an Alien" booth to learn about exo-planets and what life might be like on other planets. This was a great engaging activity for all ages. Each child chose a card which described the conditions on a fictional exo-planet i.e. whether it was hot, cold, watery, rocky or a gas giant. They then designed an alien which could survive on such a planet and explain why. With just Plasticine, pipe-cleaners, wool and googly eyes at their disposal, it was amazing to see how creative they could get. My favorite alien of the day was winged with big eyes underneath to see into the lower darker atmospheric layers of a gas planet and smaller eyes on top to deal with the brighter light from the upper atmosphere. The activity created a fun atmosphere to discuss the Drake equation and techniques used by astronomers to discover such new worlds, with the questions revealing the students' curiosity about discoveries made in recent years.

In the last JCMT Newsletter I wrote about the JAC's effort in the 29th Annual Kamehameha Business Canoe Race, held in Hilo Bay. I am happy to report that the JAC was able to bring home silverware from the 30th Kamehameha Business Canoe Race. Three mixed crews—again made up of engineers, telescope operators, and support astronomers, helped out by friends and family—competed in the novice, intermediate and open divisions.

Both the novice and intermediate crews did well, working on the experience gained by the previous year's race and the few training sessions available to work on technique and timing. The races were close and the atmosphere celebratory as everyone felt we did well. This feeling was heightened when the women's open astronomer crew came in second to the University Canoe Club. As a result the JAC has a new trophy which is on display in the kitchen area at the JAC. Hana hou everyone!

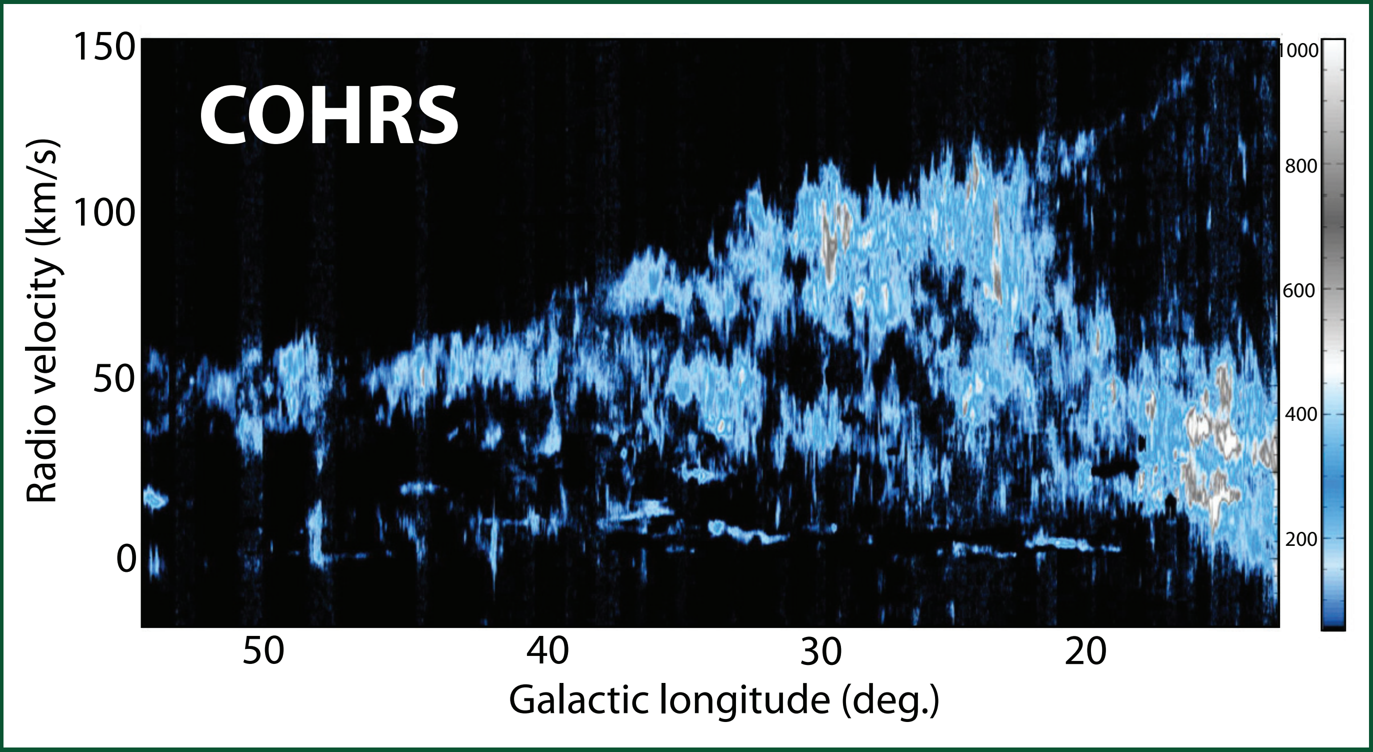
Callie's Journey Through the Universe

Callie Matulonis (JAC)

Journey Through the Universe 2013 marked my 6th year of participating in this nationally recognised programme, and it was all the more meaningful to me since this year was dedicated to the memory of Dr. Richard Crowe. It was a privilege having Dr. Crowe as an astronomy professor at the University of Hawaii at Hilo, and I cannot put into words how much he inspired and encouraged me.

The Journey Through the Universe classroom visits provide a good ego boost (we are treated like heroes!) and are an excellent reminder of how much of an impact we can have when we share our knowledge. The students are always engaged and enthusiastic, and this year was no exception. The 4th graders from Waiakeawaena Elementary School with whom I had the opportunity to visit with are bright, very interested in astronomy, and even keen to know how to get a job on Mauna Kea. They had questions about black holes and the new status of Pluto, and were eager to be involved in the hands-on activities I had planned. This year I brought with me various images from Mauna Kea observatories. The students formed groups, where they became the astronomers, and I gave each group an image. They were asked to estimate the number of stars and note colours, shapes, and anything else they observed. Then they were magically transported to a scientific conference where I introduced them as astronomers and they presented their findings to the class. Afterwards, I described objects we see with telescopes such as galaxies, nebulae, stars (colours, ages, temperatures), and star clusters, and I asked them to guess what types of objects were in their pictures. It was a fun way to encourage them to be critical thinkers, practice speaking in front of their peers, and apply information which they may already have.

The greatest joy for me is when a child from one of my classroom visits recognises me in town and says hello. The impact we can make on our local community is not to be underestimated—you never know who you might inspire.


COHRS
Radio velocity (km/s)
150
100
50
0
50
40
30
20
Galactic longitude (deg.)
1000
800
600
400
200