JCMT NEWSLETTER

JAMES CLERK MAXWELL TELESCOPE

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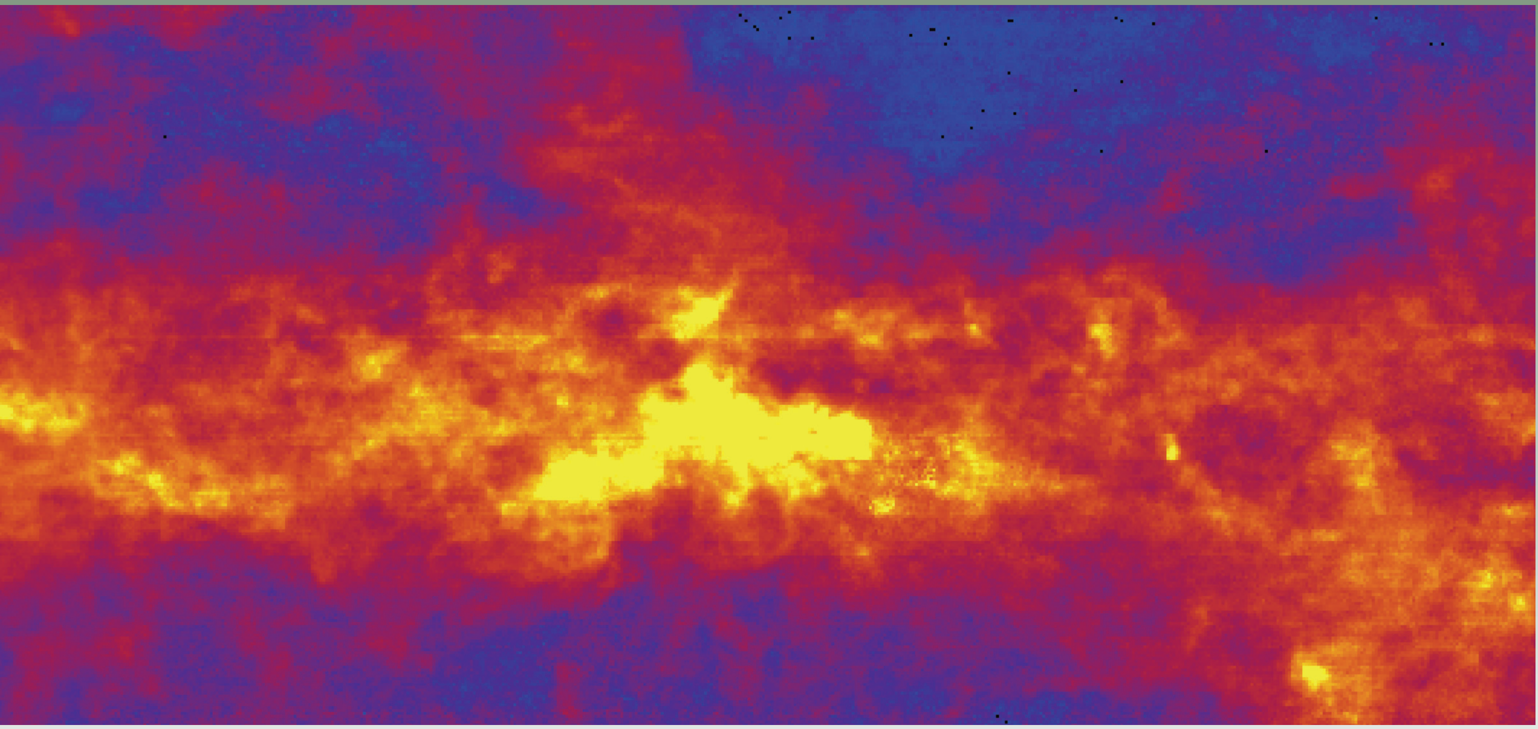


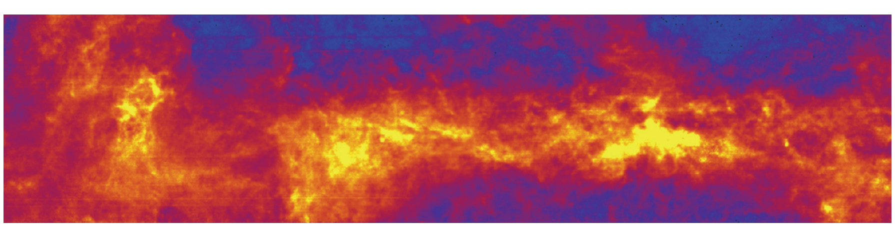
Galactic Centre

HARP $^{12}CO(3-2)$ mapping

SCUBA Polarimeter Legacy Science Results

RxWD Science Results

In This Issue



On the front and rear covers: Integrated intensity HARP $^{12}CO(3-2)$ map of the Galactic Centre. (Also see Figure 1 and article on page 15.)

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The Joint Astronomy Centre provides services and support to enable visiting and staff astronomers to undertake top-quality, front-line international-class research using the James Clerk Maxwell Telescope (JCMT) and the United Kingdom Infrared Telescope (UKIRT); to develop these facilities in order to maintain their position as the most advanced of their kind in the world; to operate them in the most cost effective and efficient manner on behalf of the funding agencies; and to be responsive to the changing needs of the contributing organizations.

The JCMT is supported by the United Kingdom's Science and Technology Facilities Council (STFC), the National Research Council Canada (NRC), and the Netherlands Organization for Scientific Research (NWO); it is overseen by the JCMT Board.

The JCMT is a member of the RadioNet consortium.

From the Desk of the Director

Professor Gary Davis (*Director JCMT*) & Antonio Chrysostomou (*Associate Director JCMT*)

Gary Davis, Director JCMT

The most significant event at the JAC in the period since the last newsletter was the untimely death of a long-serving staff member, Mark Horita; see the dedicated article elsewhere in this newsletter.

Most readers of this column will know that the JCMT is in the midst of a profound transformation, in which virtually the entire instrument suite is being replaced or upgraded. The science driver for this extreme makeover is the need to capitalise on the JCMT's trail-blazing successes of the past by carrying out large-area surveys of the submillimetre sky in both continuum and spectroscopic modes.

The spectroscopic part of this transformation is virtually complete. HARP, the world's first array receiver in the 345-GHz band, is now our workhorse instrument, and the upgraded RxWD provides world-leading sensitivity in the 690-GHz band. RxA3 continues to provide reliable service in the 230-GHz band, and ACSIS now serves as the backend spectrometer for all of these. These new capabilities have proved to be a great success, with HARP in particular being used for three projects in the JCMT Legacy Survey. The only remaining element of the spectroscopic instrumentation is ROVER, the polarimeter for RxA3 and HARP, which is being commissioned as and when time permits amongst our other priorities.

The continuum part of this transformation is unfortunately running well behind schedule, due primarily to the late delivery of SCUBA-2 and its arrays. The instrument itself was delivered in March 2008, and although the initial integration work over the course of that summer turned up some unexpected problems, solutions to all of them have since been identified and put in place. The first two science-grade arrays were delivered in July and installed in August, and as we write this column, the instrument check-out phase is in progress. We have implemented a fast-track approach in which the functionality of the instrument will be verified and the instrument will be commissioned over the course of September through November, leading to a phase of shared-risk observing in December and January. By the time you read this column, the call for shared-risk proposals might already have been issued.

The delays in this programme have led to a number of potentially serious difficulties. One is the lack of a continuum instrument on the JCMT since SCUBA was retired in July 2005 (apart from a 3-month visit by AzTEC later that same year). Fortunately, in part because there is no realistic competition for SCUBA-2's promised capabilities, this has not been a serious problem and we have detected no loss of enthusiasm in our user community for SCUBA-2 and the projects in the JCMT Legacy Survey; on the contrary, we are asked anxiously about progress with SCUBA-2 everywhere we go! A second difficulty is the increase in the cost of the instrument with every delay, and it is entirely possible that further cuts to observatory operations will be necessary in order to help pay for it.

The mention of money brings us to the third and most profound difficulty occasioned by the delay in SCUBA-2. The funding agencies in the UK, Canada and the Netherlands are all operating under very constrained financing at present, and although they have all committed to the continued operation of the telescope until 2012, the future beyond that date is by no means certain. Each of the three countries has its own unique story to tell, but from the observatory's point of view it is abundantly clear that getting science results out of SCUBA-2 as quickly as possible is absolutely essential. This is, in fact, the rationale for the fast-track approach described above.

Antonio Chrysostomou, Associate Director JCMT

In the meantime the JCMT Legacy Survey with HARP continues. Since the last edition of the Newsletter we have seen the Nearby Galaxies Legacy Survey reach almost 90% completion, the Gould Belt Survey 60%, and the Spectral Legacy Survey are now more than half-way through their project. As always you can keep up with the general progress of the JLS at `http://www.jach.hawaii.edu/JCMT/surveys/JLS_status.html` .

We have also seen the JCMT Science Archive (JSA) and the ORAC-DR pipeline advance. Reduced data products have been available from the JSA for a while now. After each night's observing, all data used to be reprocessed on machines at the JAC and the reduced products shipped over to CADC for ingestion into the JSA. This September, an important milestone was reached when this nightly re-reduction processing was transferred over to the fast machines at CADC. As well as the dramatic increase in processing power, this gives us increased flexibility as to when and how often we can process (or reprocess) data and fulfils one of the requirements of the project. We now intend to go through the backlog of data to bring the archive up to date.

(Director's Desk, continued on page 4)

JCMT Science Archive (JSA) Update

Frossie Economou (*JAC Software Group*)

More than 10,000 processed files are now available for ACSIS data from the JCMT Science Archive. These data were reduced by our pipeline in "full on" mode (as opposed to the shove-data-out-the-door-as-quickly-as-possibly mode that most visiting observers see running at the Mauna Kea summit).

Our ORAC-DR recipes have matured considerably since we embarked on this, so the more recent your data, the better it will look. When resources allow, we'll go back and re-reduce the backlog to improve early reductions and process data from before the pipeline was available. PIs who would like products from older ACSIS data generated with the latest version of the pipeline can jump the reprocessing queue by emailing `jcmtarch .at. jach.hawaii.edu` with their project ID(s).

(JCMT Science Archive, continued on page 5)

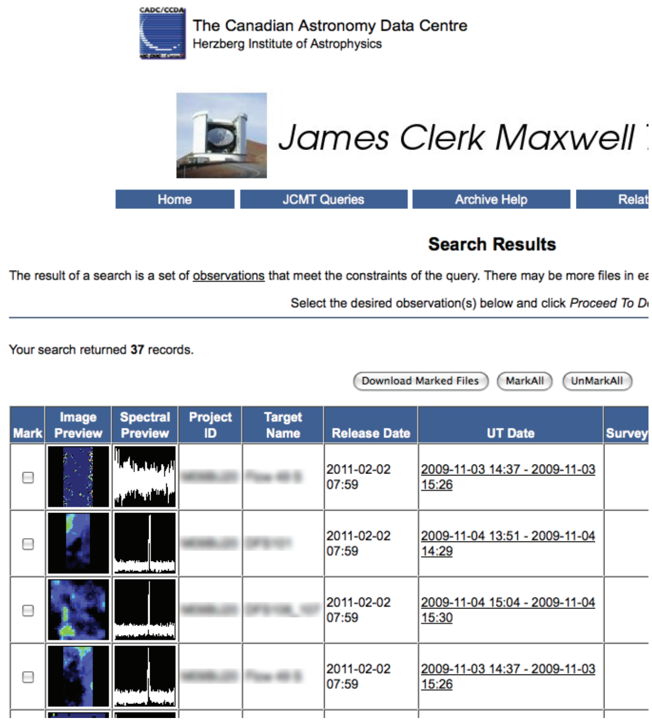

Figure 1. — An example of thumbnails from data search results at the JCMT Science Archive (JSA).

(Director's Desk, continued from page 3)

These reduced data products are processed by the ORAC-DR pipeline using advanced methods that also incorporate pre-defined quality assurance (QA) algorithms, filtering out the good data from the bad at the level of individual spectra. This development of the QA pipeline has been driven by the requirement to uniformly process JLS data but it is available to all users. An article in this newsletter gives an outline of how ORAC-DR recipes can be tailored by users for their own purposes and requirements. The pipeline is always being developed and improved. If you would like to keep up with the latest cutting-edge releases you can keep your installation up to date by following the instructions at `http://starlink.jach.hawaii.edu/starlink/rsyncStarlink`.

Finally, we have just a few staffing changes to report on this occasion. The JAC's Finance Officer, Christine Campbell, and her husband Ian, Electronics Engineer, left at the end of August to return to their native Scotland. Christine and Ian were immensely valuable to us, both in their professionalism and in their contribution to the social life of the JAC, so it is no exaggeration to say that we will miss them. Mark Millard, who was formerly with the RCUK Shared Services Centre in Swindon, UK, has joined us as Christine's replacement, bringing to an end a happy phase in which we had no Manchester United supporters on staff. A replacement for Ian has been recruited and will be joining us in November; his footballing allegiance has not yet been ascertained (it's not a question on our application form).

Figure 3. — The Director JAC bids a fond aloha to Ian and Christine Campbell.

Starlink Software Collection: Nanahope Release

Brad Cavanagh (*JAC Software Group*)

On July 27 the Joint Astronomy Centre released the 'Nanahope (Pollux)' version of the Starlink Software Collection. In addition to the usual bug-fixes and tweaks, a number of important feature enhancements have been made. These include the ability to use GAIA to visualise irregular 2-D and 3-D clumps of emission detected by the CUPID package (see Figure 1), support for accessing Virtual Observatory images and catalogues within GAIA, updated advanced data reduction recipes for ACSIS data by ORAC-DR, and the ability to process older (2006 and 2007) ACSIS data with MAKECUBE. History for all ancestors of an NDF can also be retained, allowing for better tracking of data processing.

For further information, including download links, please visit `http://starlink.jach.hawaii.edu/` . The Nanahope version is available for 32- and 64-bit Linux, and PPC and Intel OS X.

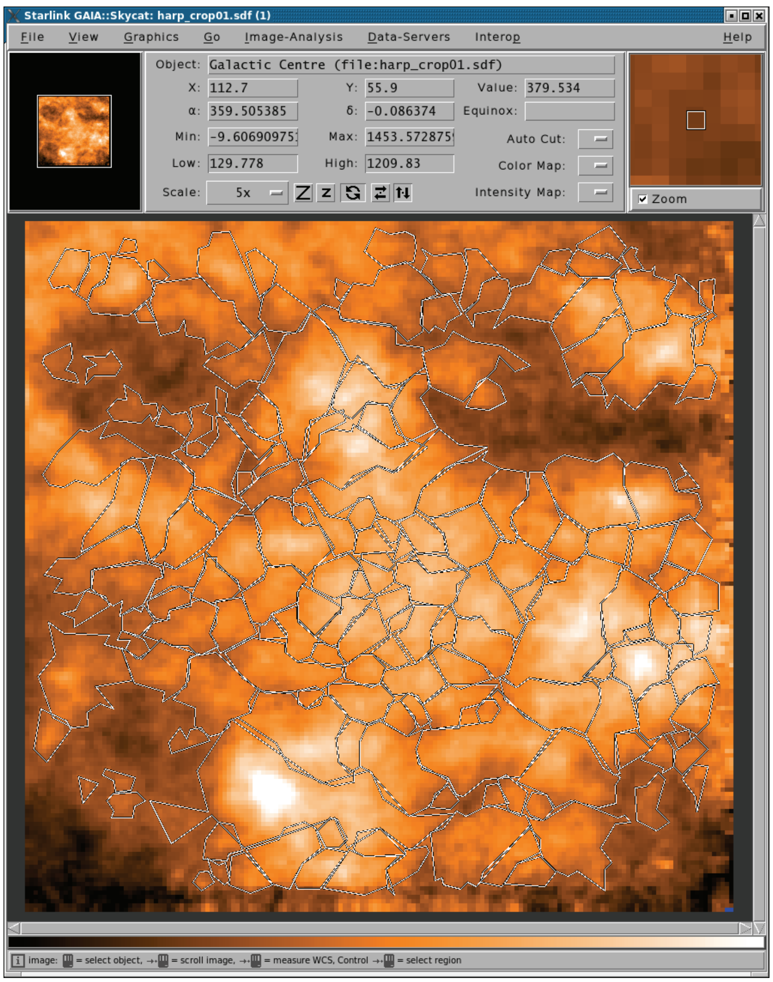

Figure 1. — Clumps detected by CUPID/FINDCLUMPS are overlaid on a Galactic Centre map in GAIA.

(JCMT Science Archive, continued from page 4)

One bonus of having processed data available in the JSA is that you now get thumbnails in your search results showing you a representative image and spectrum for your data. These can help you to quickly decide whether to launch the full image preview and/or download the full data set.

The representative image is generated from the collapsed cube of just the emission regions in the reduced cube. The representative spectrum is the spectrum at the brightest point.

For the latest JSA news and to have your say, monitor the RSS feed of our blog at `http://pipelinesandarchives.blogspot.com/` .

The SCUBA Polarimeter Legacy Catalogue

Brenda Matthews (*HIA/NRC*)

SCUPOL, the polarimeter for SCUBA, was the most prolific thermal imaging polarimeter built to date. Although it was used by a fraction of the general SCUBA user community, the archive of SCUPOL data is surprisingly large. Between 1997 and 2005, observations of 104 regions were made at 850 μm in mapping mode. These observations have resulted in ~50 refereed journal publications with new publications still appearing.

The creation of the SCUPOL Polarimeter Legacy Catalogue involved the systematic re-reduction of all imaging polarimetry made in the standard "jiggle-map" mode from the SCUBA archive (>2800 individual observations!) to produce a catalog of SCUPOL images and tables. The results of the reduction can be accessed through the published article by Matthews et al. (2009, ApJS, 182, 143) or online through the CADC's SCUBA Polarimeter Legacy Catalogue, at http://www.cadc-ccda.hia-iha.nrc-cnrc.gc.ca/community/scupollegacy/ .

The published paper includes figures for each of the 83 regions in which significant polarization was detected (see Table 1) and data tables for both science targets and planetary data. The CADC archive contains the data cubes in FITS and SDF formats for each of the 83 regions as well as planetary data, useful for verification of the instrumental polarization and evaluation of potential sidelobe contamination. The science sample containing detections is comprised of 48 star-forming regions, 11 individual YSOs (or T Tauri stars), nine Bok globules, six starless or prestellar cores, two post-AGB stars, two planetary nebulae, two supernova remnants, two external galaxies and our own Galactic center. For 39 regions (identified by asterisks in Table 1), the catalogue contains the first publication of the SCUPOL data, in whole or in part.

There are important exclusions from the dataset. Foremost is the exclusion of all polarization data taken in photometric mode. The exclusion of these data results, in a few cases, in the legacy catalogue listing targets as non-detections while detections (driven by photometric data) can be found in the literature. Raster map data were also excluded; the only existing such case in the literature is the Crab Nebula scan map data in the SCUPOL commissioning paper (Greaves et al. 2003). Data were also omitted where there was no tau solution for the date of observation (Jenness et al. 2002). In this case, the data are listed as "unusable" but it is important to note that this is not the same thing as "bad". Other data do not conform to the standard observing mode eventually adopted for the instrument and therefore require nonstandard reduction techniques not employed in our analysis (*i.e.*, there is also a difference between "nonstandard" and "bad" data). In most cases, data excluded for this reason were taken early in SCUPOL's lifetime, before the standard techniques were adopted.

Figures 1 through 4 are examples from the Legacy Catalogue. In all cases, the legacy paper contains the first publication of these data.

The ultimate goal of the project was to provide a set of reduced data to the community. Ward-Thompson et al. (2009) have already made use of the legacy catalogue data toward two Bok Globules. A paper is in preparation (Vaillancourt & Matthews) to compare the SCUPOL data to 350 μm data from the CSO Hertz polarimeter for the 14 regions in common.

The figures, tables and data cubes generated may not meet the needs of all researchers in their present form. In some cases, more binning

(SCUPOL, continued on page 7)

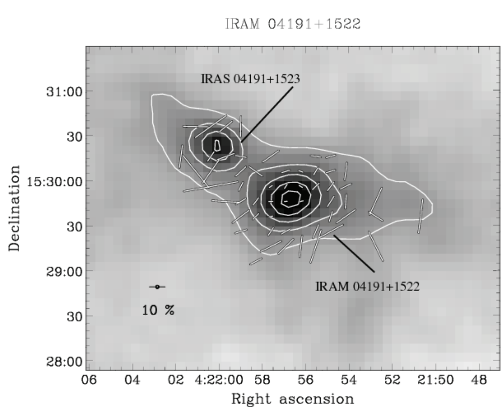

Figure 1. — The Very Low Luminosity Object IRAM 04191+1522 polarization vectors are plotted on the SCUBA Legacy Catalogue image (Di Francesco et al. 2008). The contours range from 0.05 Jy/beam in steps of 0.05 Jy/beam. The polarization data are sampled on a 10arcsec grid, and vectors are plotted where I>0, p/dp>2 and dp<4%.

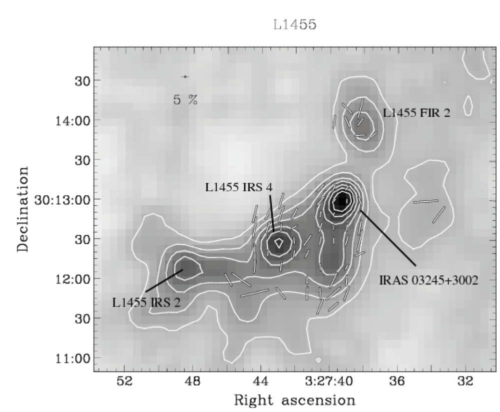

Figure 2. — The molecular cloud L 1455 shows significant polarization. The greyscale and vectors are as for Figure 1.

(SCUPOL, continued from page 6)

may be desirable to increase the signal to noise, or more stringent selection criteria will need to be applied.

References

Greaves, J., et al. 2003, *MNRAS*, 340, 353.
Jenness, T., et al. 2002, *MNRAS*, 336, 14.
Matthews, B., McPhee, C., Fissel, L., & Curran, R. 2009, *ApJS*, 182, 143.
Ward-Thompson, D., Sen, A., Kirk, J., & Nutter, D. 2009, *MNRAS*, 398, 394.

Table 1.

Science Targets

Star-Forming Regions	*Star-Forming Regions (cont.)*	*Star-Forming Regions (cont.)*	*Young Stellar Objects (cont.)*	*Bok Globules (cont.)*
W3	NGC 6334 A	(Perseus 5)	[L483]	[CB 16]
* W3 North	* G011.11-0.12	(Perseus 7)	[L723]	[CB 24]
* W3 OH	* GGD 27	(NGC 6334)	[L1157]	[CB 25]
* AFGL 333	* CRL 2136 IRS 1	(GF 9)		
GL 437	Serpens MC	[IRAS 22551+6221]	*Starless/Prestellar Cores*	*AGB Stars*
* L1455	* CL 04/CL 21		L1287	* IRC+10216
* NGC 1333	* G28.34+0.06	*Young Stellar Objects*	L1498	CRL 2688
Barnard 1	* IRAS 18437-0216	* L1448	L1517B	(CRL 618)
HH 211/IC 348	W48	* IRAS 03282+3035	L1544	
* RNO 43	R Cr A	* L1551	L183	*Planetary Nebulae*
OMC-1	W49	* L1527	L43	* NGC 6302
* OMC-2 & OMC-3	W51	* IRAM 04191+1522		NGC 7027
NGC 2024	* IRAS 20081+2720	* VLA 1 IRS 2	*Bok Globules*	(NGC 6537)
* LBS 23	IRAS 20126+4104	* HH 111	* CB 3	
NGC 2068	IRAS 20188+3928	* IRAS 16293-2422	* CB 17	*Supernova Remnants*
NGC 2071 IR	S106	AFGL 2591 IRS	CB 26	* Crab Nebula
* IRAS 05490+2658	* G079.3+0.3	Cep A	* CB 34	Cas A
Mon R2 IRS1	* DR 21	Cep E	CB 54	
* IRAS 06381+1039	* G81.56+0.10	(DG Tau)	CB 68	*External Galaxies*
* Mon IRAS 12	S140	(Elias 16)	B335	M82
* IRAS 08076-3556	S146	(Elias 24)	CB 230	* M87
ρ Oph A	S152	[GM Aur]	CB 244	
* ρ Oph C	NGC 7538	[AS 205]	(CB 243)	*Galactic Centre*
* ρ Oph B2	S157	[L1709B]	[CB 4]	

Note: Regions which contain heretofor unpublished data (in whole or in part) are noted with an asterisk. Targets with useable data but non-detection are enclosed in parentheses, and square parentheses indicate regions with no useable data (for details, see Matthews et al. (2009).

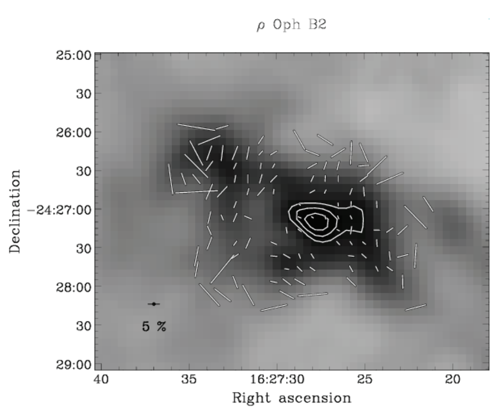

Figure 3. — The ρ Oph B2 core is shown with contours ranging from 0.6 Jy/beam in steps of 0.05 Jy/beam. The vector sampling and selection criteria are as for Figure 1.

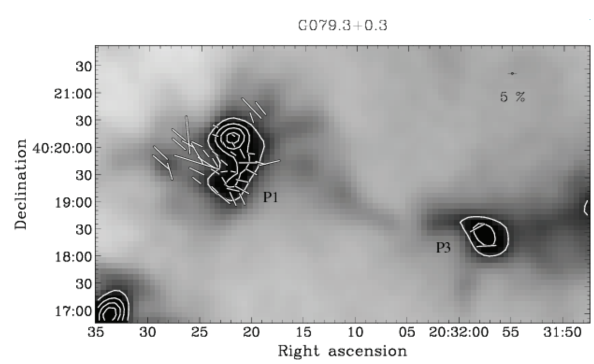

Figure 4. — The MSX cloud G079.3+0.3 polarization appears to align along the filamentary structure of the cloud. Contours range from 0.5 Jy/beam in steps of 0.25 Jy/beam. The vector sampling and selection criteria are as for Figure 1.

The 3-D Structure of Molecular Gas Around PWN G 63.7+1.1

Roland Kothes (*HIA/NRC*), Henry Matthews (*HIA/NRC*), Samar Safi-Harb (*Manitoba*), & Chris Brunt (*Exeter*)

A pulsar wind nebula (PWN) is a bubble of magnetic field and ultra-relativistic electrons and positrons. This bubble is inflated by the wind of a central pulsar and draws its energy from the pulsar's spin-down luminosity. The interaction of the electrons and positrons with the magnetic field produces a centrally peaked synchrotron nebula, that can be observed over a wide frequency range from radio to γ-ray. Since a pulsar is formed in a supernova explosion the PWN is initially surrounded and confined by a shell-type supernova remnant.

The radio source G 63.7+1.1 (Figure 1) was identified as a PWN by Wallace et al. (1997) based on its flat radio continuum spectrum, a centrally peaked radio morphology, and the detection of linearly polarized radio continuum emission. They did not find evidence for a shell-type remnant surrounding the PWN, but they believe that an arc-like feature on top of the PWN represents a part of the SNR shell moving either towards us or away from us and interacting with dense ambient material. Wallace et al conclude that G 63.7+1.1 is associated with features observed in HI and CO near the tangent point interacting with that arc-like feature at radial velocities between +21 and +25 km/s resulting in a kinematic distance of 3.8 kpc. This gives the PWN a diameter of 8.6 pc, which makes it one of the largest of its kind.

Inspection of new ^{12}CO(1-0) data observed with the 14-m telescope of the Five College Radio Astronomy Observatory and the HI data of the Canadian Galactic Plane Survey (CGPS, Taylor et al., 2003) revealed that there may be more gas clouds related to the PWN at other radial velocities (Figure 1). In addition to the structures discussed by Wallace et al, we found a hole in the HI emission that has exactly the same size and shape as G 63.7+1.1 at about +13 km/s and two more molecular clouds at about +11 and +14 km/s, one of which is a horseshoe shaped feature which has the point like infrared source IRAS 19463+2727 at its end. This IRAS source coincides with a flat-spectrum, unpolarized, unresolved radio source in the CGPS,

(PWN G 63.7+1.1, continued on page 9)

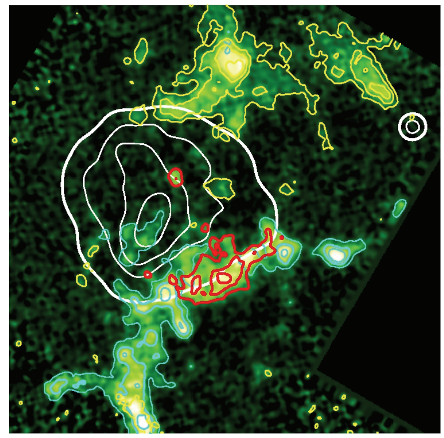

Figure 2. — CO(3-2) emission integrated between radial velocities of about +8 and +25 km/s. The white contours indicate the radio continuum emission of the PWN. The three clouds with different velocities from Figure 1 are indicated by appropriately colored contours.

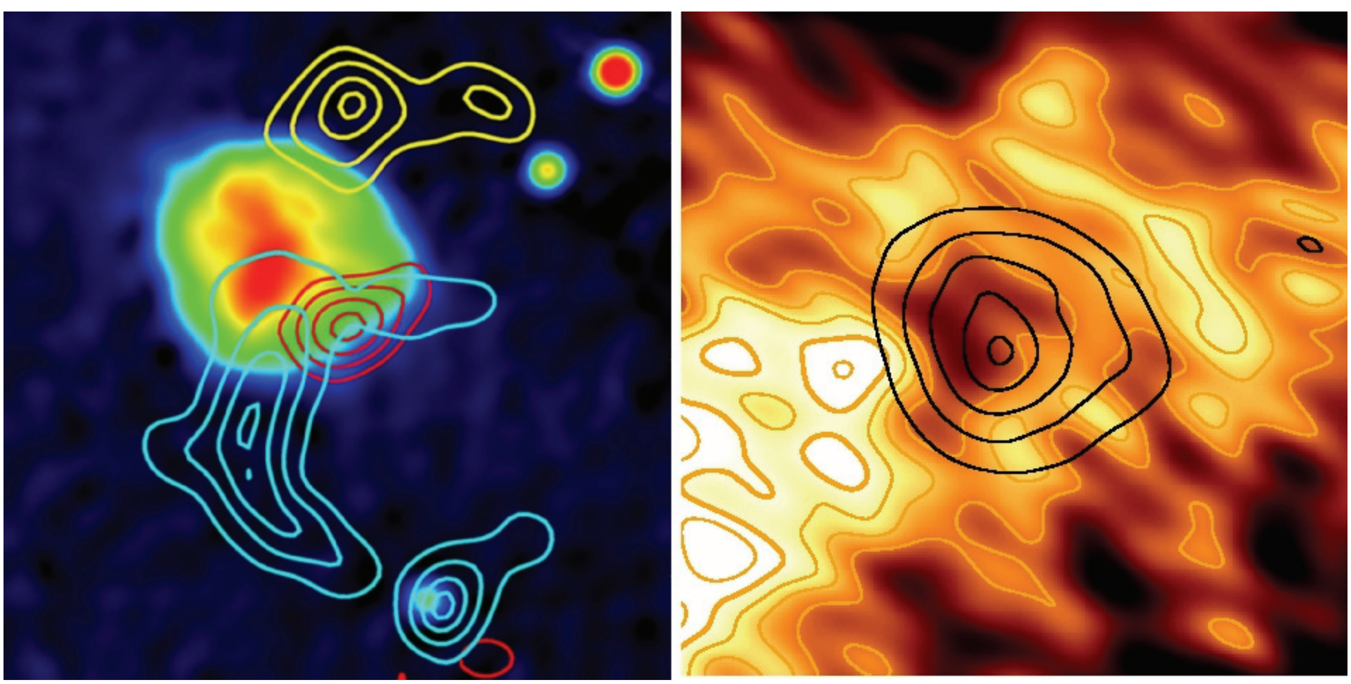

Figure 1. — Left panel: 21 cm radio continuum image of G 63.7+1.1 taken from the Canadian Galactic Plane Survey. Contours indicate molecular clouds in the vicinity at central radial velocities of +11 km/s (blue), +14 km/s (yellow), and +22 km/s (red, the Wallace et al. cloud). Right panel: Channel map of the HI data cube towards G 63.7+1.1 taken from the CGPS. The black contours indicate the radio continuum emission of the PWN.

(PWN G 63.7+1.1, continued from page 8)

indicative of a compact HII region, probably hosting a young massive star.

We observed the area around G 63.7+1.1 in the CO(3-2) line with the JCMT in August 2008. The goal was to use the high resolution and sensitivity of the JCMT to probe the molecular clouds for dynamical connections and any kind of indication for an interaction with the PWN. This would result in a more accurate distance estimate and an investigation of the impact on its environment of the only known PWN to directly interact with a molecular cloud. In addition we wanted to study a possible relation between G 63.7+1.1 and IRAS 19463+2727.

Kothes et al. (2009, in prep) found strong evidence that the arc-like radio continuum feature is a toroidal internal structure linked to the pulsar wind, like many other tori found around young pulsars with the CHANDRA X-ray telescope (e.g. Kargaltsev & Pavlov, 2008). This weakens the case for the CO feature at +22 km/s.

The combination of the CGPS HI data with the high-resolution JCMT CO(3-2) data reveals a more likely scenario. We propose that G 63.7+1.1 is located inside the HI hole at +13 km/s (Figure 1). Since the SNR carved out this hole from the hydrogen cloud the HI emission outside the PWN is not affected by acceleration by the SNR shock wave and its velocity should represent the actual Galactic rotation at its position. In this case the diameter of the PWN decreases to 3 pc (*d*=1.3 kpc) more typical for a PWN. The "yellow" cloud (Figure 2) would be moving away from us relative to the HI and the cloud in blue moving slightly towards us. Taking the cube and displaying it three-dimensionally (Figure 3) indicates that the yellow and blue cloud are dynamically connected. The blue cloud has a gap in the centre area where the continuum emission of the PWN overlaps with it, likely created when this part was hit by the supernova shock wave. Interestingly the red cloud which is centered at about +22 km/s fit exactly into this hole. Whether this cloud could have been accelerated by the supernova shock wave is not clear. The cyan cloud connects the PWN with IRAS 19463+2727, which contains a strong bipolar outflow (Figure 4) indicating that it is still a very young object. The supernova explosion that created the PWN cannot be responsible for the formation of the star(s) inside IRAS 19463+2727 because the time scale of a supernova explosion is too small. However, since the progenitor of G 63.7+1.1 and the star(s) inside IRAS 19463+2727 were formed from the same parent cloud their formation may have been triggered by the same event.

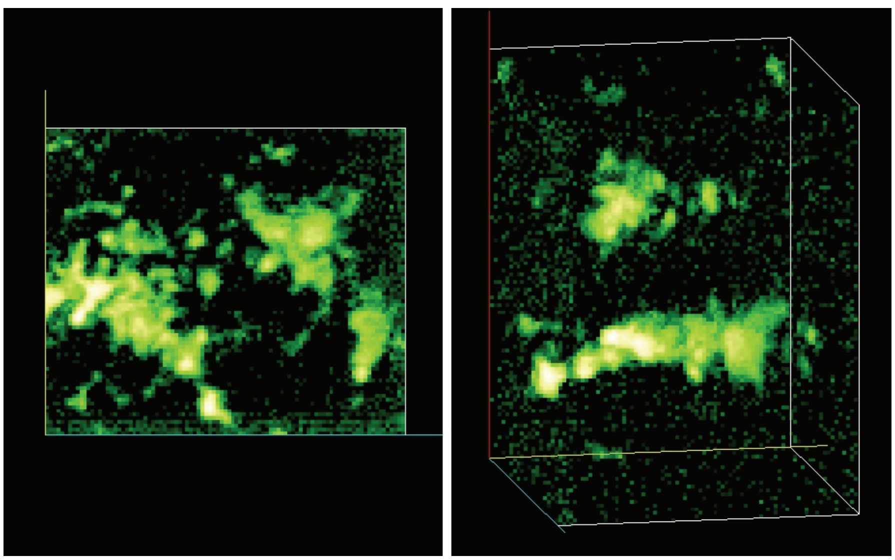

Figure 3. — Three dimensional representation of the CO(3-2) data cube between RA of 19h48m13s and 19h47m21s, Dec of 27°38'12" and 27°47'41", and a radial velocity of +3 and +32 km/s. The axis are represented by blue (RA), yellow (Dec), and red (velocity) lines. The image shows along each line of sight the brightest pixel. In the left image the line of sight is parallel to the velocity axis. In the right is the yellow cloud and the blue and red clouds are in the left. The right image represents the cube rotated around the RA and Dec axis each by 100 degrees. The red cloud is now at the top and the blue and yellow clouds at the bottom.

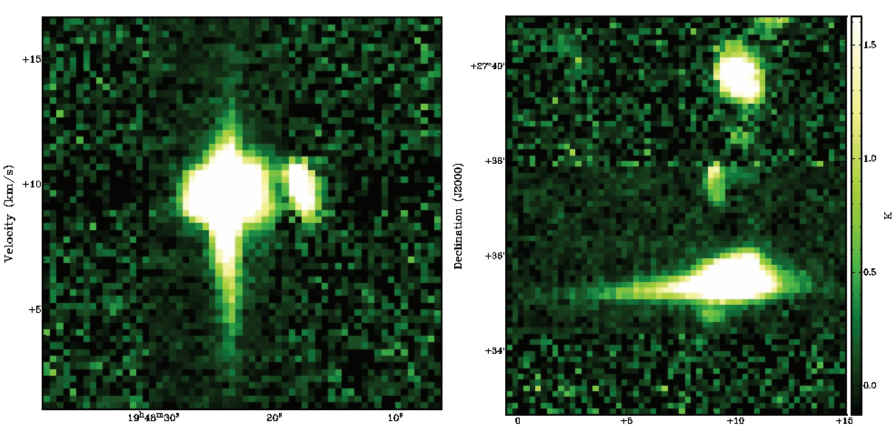

Figure 4. — RA-velocity and velocity-Dec images of the outflow in IRAS 19463+2727.

References

Kargaltsev O., Pavlov G.G., 2008, astro-ph, 0801.2602.
Taylor A.R., Gibson S.J., Peracaula M., et al., 2003, AJ, 125, 3145.
Wallace B.J., Landecker T.L., Taylor A.R., 1997, AJ 114, 2068.

CO(6–5) Emission from Arp 220: Piecing Together the Puzzle of This Enigmatic ULIRG

Padelis Papadopoulos (*Bonn*), Kate Isaak (*Cardiff*),
Paul van der Werf (*Leiden*), & Manolis Xilouris (*Athens Observatory*)

Arp 220 is the most local, brightest and perhaps best-studied example of the "ultraluminous" class of galaxies. It has been adopted as the archetypical extreme starburst galaxy and its broadband spectral energy distribution (SED) is used extensively not only to benchmark observations of local ULIRGs but also in galaxy evolution models to predict the observability of high-redshift objects and the outcomes of future deep, cosmological surveys across many wavebands. This is particularly the case in the submillimetre/FIR regime where both molecular line and continuum templates of Arp 220 are used to predict the outcomes of SCUBA-2, Herschel and ALMA suveys.

Arp 220 is, however, a peculiar object in many ways, not least because of the deficiency observed by ISO of emission from the 157 μm C^+ line, a powerful diagnostic of the conditions in starforming regions. The galaxy has been the target of many observational campaigns at millimetre and submillimetre wavelengths, however it is only recently that observations of the higher frequency lines have been possible because of their large linewidths and the corresponding requirements this places on the spectrometer bandwidths needed (~1000 km/s FWZI, >2 GHz coverage at 700 GHz).

The recent full commissioning of the high-frequency channels of the sensitive, dual-channel receiver RxWD has made possible observations of the CO(6–5) emission line with the JCMT. In March 2009, after many weathered-out trips to the telescope waiting for appropriate D-band observing conditions (*i.e.*, the very best), we observed Arp 220 as part of the final stages of a large survey of the molecular line emission from a sample of ULIRGs and LIRGs (Papadopoulos et al., 2007a, 2007b, 2007c).

We used ACSIS in its widest mode of 1.8 GHz and, with two LO tunings, were able to cover an effective bandwidth of 3.2 GHz (c. 1400 km/s). Using the fastest beam switching mode available (continuum mode, beam switch 4 Hz with a 30" throw in azimuth) we were able to achieve very flat baselines — essential for observations of very faint, broad emission lines. Typical system temperatures were 2000–3000 K, and the measured beam size and aperture efficiency at 691 GHz c. 8" and $\eta^*_{ap} \approx 0.32$ respectively. Strong spectral pointing sources at 700 GHz are few and far between, and so we used a combination of absolute pointing with RxWD and differential pointing

(ARP 220, continued on page 11)

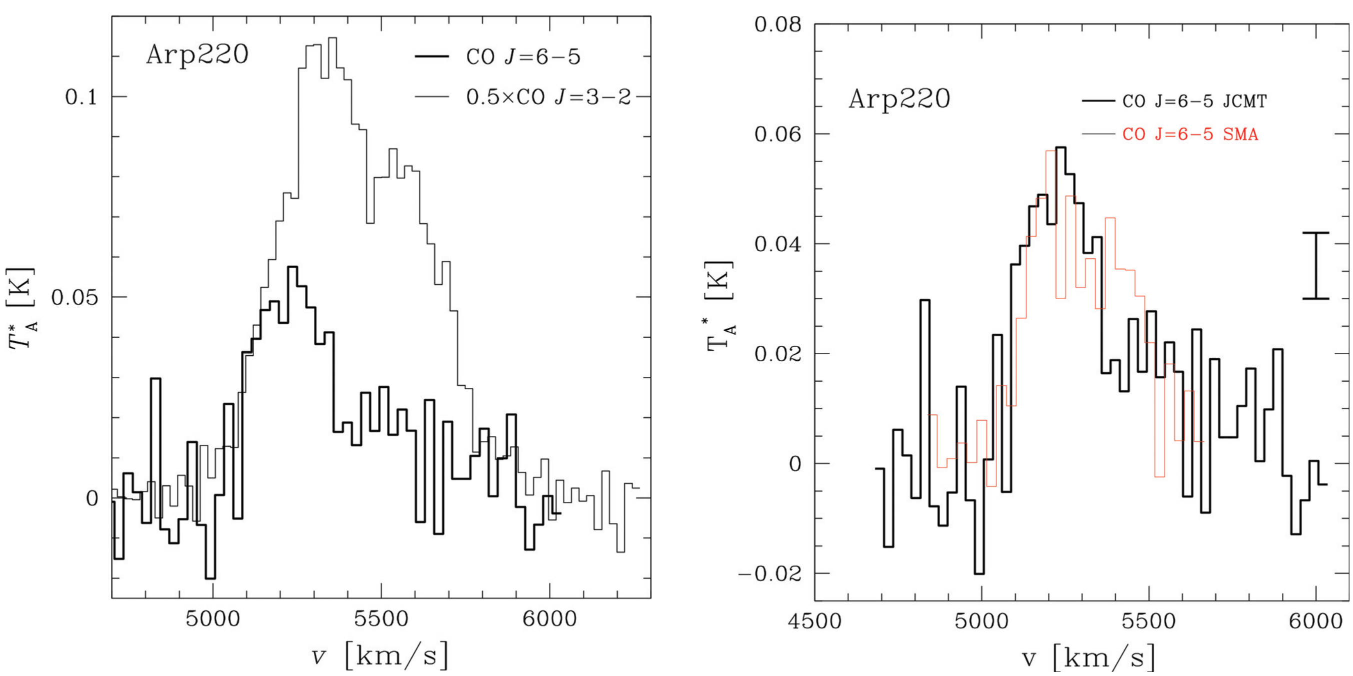

Figure 1. — Arp 220: α=15^h 34^m 57.24^s, δ=+23°30'11.2" (J2000). Left panel: CO J=6–5 (thick line), overlaid onto CO J=3–2 (thin line), with resolutions of ΔV_{ch}=27 km/s (J=6–5) and ΔV_{ch}=23 km/s (J=3–2), and centered at cz=5450 km/s (LSR). The thermal rms error across the line-free part of the spectrum is δT_A~12 mK for both lines. Right panel: the JCMT spectrum overlaid with that obtained by the SMA (×7 to bring them on similar scales) on the same cz velocity scale (SMA spectrum adopted from Matsushita et al. 2009).

(ARP 220, continued from page 10)

with RxA3, with our residual pointing errors coming to only c. 1.4" rms.

Our final spectrum is shown in Figure 1, along with an overlay of the CO(3–2) and then a spectrum of the CO(6–5) emission measured with the SMA. We derive fluxes of $S_{CO(6-5)}$=(1170±341) Jy km/s, and $S^{cont}_{442\ um}$=(3.71±0.96) Jy using the line-free part, or equivalently $S^{(c)}_{434\ um}$=(3.57±0.92) Jy (scaled by $S_\nu \propto \nu^2$). The values are in good agreement with those published recently by Matsushita et al. 2009 of $S_{CO(6-5)}$=(1250±250) Jy km/s and $S^{(c)}_{434\ um}$=(2.5±0.8) Jy using the SMA, proving that the corresponding submm maps collect all the line and dust continuum flux. This is unsurprising given that single dish and interferometrically measured fluxes of the CO J=1–0, 2–1 lines, (expected to be more extended than the high-excitation J=6–5 line which traces much warmer and denser gas), are in excellent agreement (Downes & Solomon 1998). This is also the case for the CO J=3–2 line, recently imaged with the SMA by Sakamoto et al. (2008), where they report $S_{CO(3-2)}$=(3200±500) Jy km/s, in excellent agreement with the JCMT value obtained by Greve et al. (2009) of $S_{CO(3-2)}$=(3168±634) Jy km/s.

Whilst the agreement of our observations with those of the SMA is excellent, the CO J=6–5 line itself is much fainter than one might expect from observations of lower-J CO transitions, HCN and CS. The observed CO(6–5)/(1–0), (6–5)/(3–2) brightness temperature ratios are $R_{65/10}$~$R_{65/32}$~0.08 respectively, much lower than those expected from the warm and dense molecular star-forming gas in this extreme starburst. We attribute the depressed CO J=6–5 emission to high optical depths, with $\tau(\nu \gtrsim 350\ \mathrm{GHz}) \gtrsim 1$. Dust attenuation will strongly strongly modify lines at higher frequencies, and the same high optical depths are very likely to be responsible for the well-known observed deficiency in C^+. Based on our observations, we anticipate that Herschel will reveal very faint and even absent CO and HCN molecular transitions beyond ~690 GHz (Figure 2).

The implications of high-opacity are not restricted to the local Universe. Low CO (high-J)/(low-J) line ratios have also been found in several starbursts at high-redshift, and these could also be due to high dust optical depths at sub-mm wavelengths. High dust optical depths at far-IR/submm wavelengths can affect the diagnostic power of molecular lines in the spectral regime where it is expected to be the greatest, making their intensity ratios depend on differential absorption and viewing angle rather than underlying gas excitation conditions.

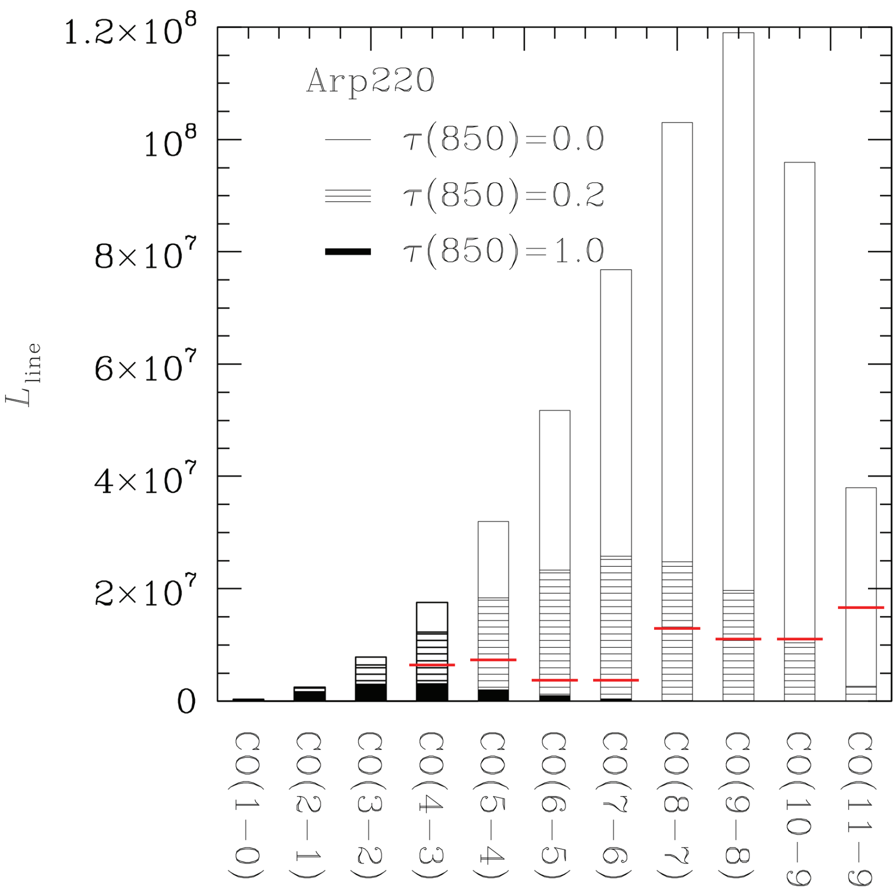

Figure 2. — Spectral line energy distributions for Arp 220 illustrating the effects of dust. The red lines denote the 5σ 1 hr sensitivities of the Herschel-SPIRE FTS.

References

Downes D., & Solomon, P. M. 1998, ApJ, 507, 615.
Matsushita S., Iono D., Petitpas G., et al. 2009, ApJ, 693, 56.
Sakamoto K., Wang J., Wiedner M. C., et al. 2008, ApJ, 684, 957.
Greve et al., 2009, ApJ, 692, 1432.
Papadopoulos, P., isaak, K.G., & van der Werf, P., 2007, ApJ, 668, 815.
Papadopoulos et al. 2007, arXiv:astro-ph/0701829.
Papadopoulos, P. 2007, ApJ, 656, 792.

Tips for Reducing ACSIS Data with the ORAC-DR Pipeline: QA Tweaks and Recipe Modifications

Brad Cavanagh (*JAC Software Group*), Remo Tilanus (*JCMT Head of Operations*), Tim Jenness (*JAC Software Group*), & Antonio Chrysostomou (*Associate Director JCMT*)

The ACSIS ORAC-DR pipeline has been through a number of development changes over the past 12-18 months. From a simple pipeline scheme to allow the observer a quick look of their data at the telescope, the pipeline can now undertake sophisticated reduction algorithms and make reduction decisions based on user-supplied data quality demands.

This article takes the reader through the commands to run the ACSIS ORAC-DR pipeline and then shows how one can tailor the pipeline to suit specific needs and requirements. It is planned that such versatility will be further enhanced in the future with the implementation of a text-based parameter file tweaking the pipeline behaviour and functionality.

Note that since the Nanahope release (see article elsewhere in this Newsletter) the ACSIS ORAC-DR pipeline now runs the advanced data reduction algorithms by default.

Running the Pipeline

The following assumes that data have been downloaded from the JCMT Science Archive at the CADC to a local disk. To run the pipeline to reduce data from a specific UT date enter the following commands:

```
$ oracdr_acsis YYYYMMDD

$ setenv ORAC_DATA_IN <path to raw data>

$ setenv ORAC_DATA_OUT <path to where reduced data will go>
```

This sets up the necessary environment variables so that ORAC-DR knows where to find the raw data and also where it will write the reduced data products to. The pipeline can now be set to reduce data with the `oracdr` command. There are several options which can be set. To get the full list just type:

```
$ oracdr -man
```

Here we include variants which you may find useful:

The following command will reduce data between observations `X` and `Y` on the UT date specified above. Note that if observations were observed in multi-subsystem mode then all subsystems will be reduced by the pipeline. The `-batch` switch ensures that the final group processing isn't done until all the individual observations have been reduced (which is not how the pipeline behaves at the summit as there it has no foreknowledge of when a group of observations will end). The ORAC-DR log is written to the screen and to a separate file (a hidden 'dot' file: `.oracdr_xxxx.log`) with the `-log sf` switch. To speed up the processing all graphical output is suppressed with the `-nodisplay` switch. The `-skip` switch ensures that any missing data files between `X` and `Y` are handled properly (*i.e.*, the gap is recognised by the pipeline and it moves on to the next in the sequence). Finally, if you want to override the data reduction recipe stored in the file headers (and originally specified at MSB creation) then one can just enter the recipe name at the end of the command.

```
$ oracdr -from X -to Y -batch -log sf -nodisplay -skip REDUCE_SCIENCE_NARROWLINE
```

If you have data from several UT dates that you wish to reduce together then you can do so by placing their directory paths and filenames into a simple text file (one line per filename) that is passed directly to the pipeline with the `-file` switch.

```
$ oracdr -file files.list -batch -log sf -nodisplay REDUCE_SCIENCE_NARROWLINE
```

This is also a useful way of reducing a single subsystem at a time by putting just those data from the same subsystem into a text file. For instance, to have just the first subsystem from observations 13 to 16 from a

(Data Reduction Tips, continued on page 13)

(Data Reduction Tips, continued from page 12)

certain UT date in a file:

```
$ ls <path to raw data>/0001[3-6]/aYYYYMMDD_*_01_000*.sdf >> files.list
```

If you also want to put all your files into one group file (normally only data observed at the same telescope position and with the same tuning are coadded into a group) then you can do this by using the `-onegroup` switch. So for instance, if you are building a big map from several rasters and would like to have a single output file then you may use the command:

```
$ oracdr -file files.list -batch -log sf -nodisplay -onegroup REDUCE_SCIENCE_NARROWLINE
```

The pipeline will now begin to reduce data and generate the reduced data products. The output files that are created are described by the text output log on the screen (the full list will be made available on the ORAC–DR web pages — `http://www.oracdr.org/`). The important files to look out for are those ending with `_reduced`, `_rimg` (or `_integ`) and `_rsp`. These are the final reduced cube, the integrated intensity and the spectrum from the brightest pixel, respectively.

Improving Your Reduced Data with Quality Assurance Parameters

There are several things that one can do to improve the quality of the reduced data products. Basic inspection of the reduced data is the first stage to determine which tweaks are necessary. Look at the group integrated intensity map (`ga*_rimg.sdf` or `ga*_integ.sdf`) as that is usually a good indicator of bad points in the data. If you see stripes running across the image then it is likely that the quality assurance (QA) tests have not been sufficiently stringent. You can also look at the individual maps (`a*_rimg.sdf` or `a*_integ.sdf`) to determine whether there is just one bad observation dominating the final product.

To affect the QA parameters copy the file in `/star/bin/oracdr/cal/acsis/qa.ini` to a local directory, renaming it something like `myqa.ini` (your choice!). Practice has shown that sometime you need a different set of QA parameters for different data sets. As such, copying the `qa.ini` file to the directory where the reduced data is being written to (*i.e.*, `$ORAC_DATA_OUT`) is probably a good idea. It will make things clearer to you when you return to this data set 2 months from now!

At this stage, it is a very good idea to make yourself familiar with the QA document which outlines the QA tests which are executed and the corresponding parameters. You can download the document from `http://www.jach.hawaii.edu/JCMT/surveys/JLSdocuments.html` . The `qa.ini` file takes on the following organisational structure:

```
[default]
...
...

[default frequency:range]
...
...

[default molecule]
...
...

[JLS_survey]
...
...

[JLS_survey molecule]
...
...

[JLS_survey frequency:range]
...
...
```

Those parameters which are under `[default]` headings are picked up by the pipeline by, well, default. The pipeline can also recognise qualifiers to this whereby the user can assign a different set of QA criteria for different frequency ranges (provide a colon-separated start and end frequency range) or a specific molecular transition. Further down the file come separate criteria which have been specified for each of the JLS surveys.

(Data Reduction Tips, continued on page 14)

(Data Reduction Tips, continued from page 13)

If you are reducing JLS data, then you can tweak the parameters under the heading appropriate for the survey. Those parameters under the `[default]` heading should be tweaked for all other data (*i.e.*, from normal PI time).

The QA document lists what all the parameters are and how they can be used. This should really be the reference guide as one proceeds with the QA tweaks. There are possibly two parameters which will probably have the most impact on data quality. These are the `TSYSBAD` and `RMSTSYSTOL` parameters. `TSYSBAD` provides a threshold limit for the measured T_{sys}, such that if any receptor has a T_{sys} greater than this value it is flagged as bad for the rest of the data processing. This test is used to trap those really badly behaving receptors. `RMSTSYSTOL` is a more subtle test but can have significant impact on the data quality *(Ed.: can anything be simultaneously subtle and significant?)*. If any individual spectrum in a time series has a measured rms which differs from the expected rms (as calculated from the T_{sys}) by this fraction, it is flagged as a bad spectrum and omitted from any further processing. A value of 0.3 means that the measured and expected rms cannot differ by more than 30% to pass this test.

Once you have tweaked the QA parameters then re-run the pipeline with the following change to the command line argument to force the pipeline to use the QA parameter file you have just amended:

```
$ oracdr -file files.list -batch -log sf -nodisplay -calib qaparams=myqa.ini REDUCE_SCIENCE_NARROWLINE
```

If you have a lot of data to reduce, then it may be prudent to run this on just one data file (the one which you may have identified earlier to have the poorest data quality) and continue to tweak the QA parameters until that individual cube is reduced to your satisfaction. Then reduce your whole data set.

Modifying the ORAC-DR Recipes

Another level of control over what the pipeline does to your data can be attained by modifying the recipes themselves. The first thing to do is to copy your recipe of choice and put it into some directory of your choice:

```
$ cp /star/bin/oracdr/src/recipes/heterodyne/REDUCE_SCIENCE_NARROWLINE ~/oracdr/recipes/
```

Before running the pipeline from the command line you'll need to tell ORAC-DR where to look for the new recipe:

```
$ setenv ORAC_RECIPE_DIR ~/oracdr/recipes/
```

If you look in the recipe, you'll find at the bottom a command which starts with `_ITERATIVE_GROUP_PRODUCTION_` followed by a number of parameters. This is the primitive which does the bulk of the data reduction.

Turning on Flatfielding

Especially during 2007-08, HARP/ACSIS data frequently suffered to striping artefacts. Thanks to a routine originally developed by Emily Curtis, we can choose to have the data flatfielded by adding `FLATFIELD=1` to the `_ITERATIVE_GROUP_PRODUCTION_` line. Care should be taken here for a couple of reasons. Firstly, this algorithm works best if the region is extended with emission across the field. This is because there is an assumption in any flatfielding routine which is that each receptor sees the same amount of flux. Clearly, for pointlike sources (or jiggle maps) this would not apply. Secondly, if the cause of the striping is not one due to genuine gain differences between receptors, then one can actually introduce stripes (or make existing ones worse).

Rebinning along the Velocity Axis

The pipeline can rebin the velocity axis to a user-defined value. The default is to not have any binning. To turn this feature on, one can add `REBIN=1.0` to the `_ITERATIVE_GROUP_PRODUCTION_` line to rebin the data to 1 km/s bins. More than one velocity resolution can be implemented. For instance, if you want to compare data with 0.3 and 1.0 km/s bins, then include the line `REBIN=0.3,1.0`.

Changing the Order for Baseline Fitting

To change the polynomial order that the pipeline uses to fit to the emission-free baselines one can add the `ORDER` parameter to the `_ITERATIVE_GROUP_PRODUCTION_` line. For instance, to use a 3rd order polynomial to fit to the data use `ORDER=3`.

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Mapping the Galactic Centre with HARP

Jessica Dempsey & Holly Thomas (*JCMT Support Scientists*)

A new CO(3–2) map of the Galactic centre region has been obtained using HARP on the JCMT. Engineering observations were undertaken in June and July of 2009 to test a new fast-mapping mode using HARP/ACSIS. Scanning at 0.1 seconds per point, two sets of maps were taken at $^{12}CO(3\text{–}2)$ of a 2×0.5 deg region of the Galactic Centre.

Since the observations were primarily designed to test the ability of the data acquisition and ACSIS to keep up with the speed of the map-taking, the observations were done in Grade 4 and 5 weather, with two of the four maps observed with $\tau>0.3$. The maps were taken in two 1×0.5 deg sections, repeated once at 1 GHz and once using the 1.8 GHz wideband mode. Each individual section was completed in under an hour.

The data were reduced solely with the ORAC-DR pipeline (details of which can be found elsewhere in this issue), including the optional flat-fielding algorithm. The integrated intensity map of the combined observations is shown in Figure 1. In a total observing time of four hours, the average sensitivity after smoothing the data to 2 km/s, was 0.5 K.

Figure 2 shows the longitude-velocity plot of the region after collapsing through the entire latitude range of the map. The horizontal absorption features appear in the velocity range −55 km/s < *v*(LSR) < +20 km/s are the foreground spiral arms; from top to bottom they are, the local arm, the 4.5 kpc arm and the 3 kpc arm (Oka et al. 2003), although these are mixed in with other arm-like signatures (Sofue,

(HARP Mapping, continued on page 16)

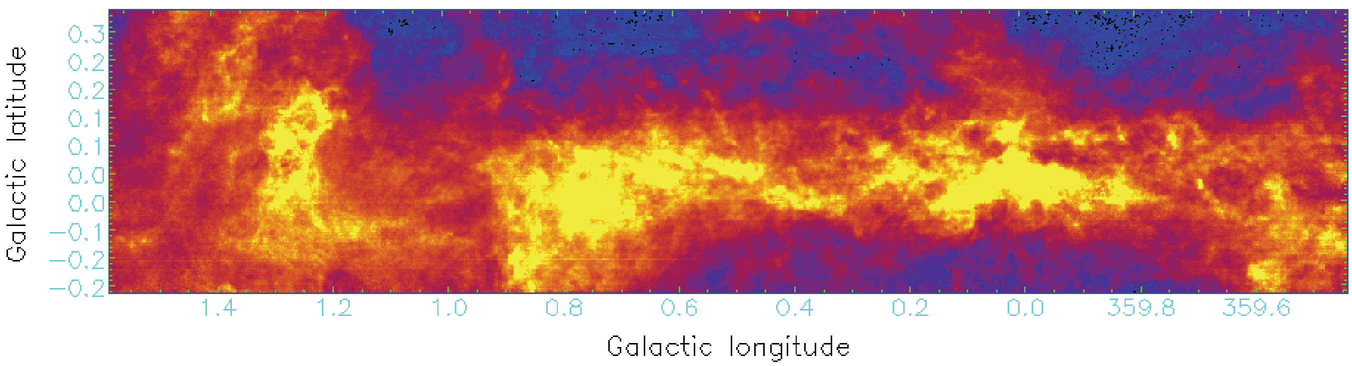


Figure 1. — Integrated intensity HARP $^{12}CO(3\text{–}2)$ map of the Galactic Centre. (Also see front and rear covers of this issue.)

(Data Reduction Tips, continued from page 14)

Changing the Thresholds for the Moments Maps

The moments maps (integrated intensity, velocity field) are calculated once the emission regions in the cube have been identified. The detection thresholds are by default 3σ and 4σ, respectively (we find that a better velocity map is obtained by having a higher threshold than for the integrated intensity). To change these add `RMS_THRESHOLD=2.0,4.5` to change these to 2σ and 4.5σ. Note that lowering the threshold for the integrated intensity map (the first of these two numbers) can make the map noisier and the pipeline run slower.

Changing the Clumpfinding Method for Finding Emission Features

The Starlink CUPID routines are used to isolate the emission regions (i.e. 3-D clumps in this context) in the reduced cubes. CUPID currently contains four different algorithms for clump detection but there are three that are used by the pipeline: ClumpFind, FellWalker, Threshold. To change the clump-finding algorithm add `METHOD=fellwalker`. The default is to use ClumpFind.

Changing the Regridding Options

There are also options for regridding to different scales and using different methods. For instance, to regrid using a Gaussian kernel of 9-acrsec width onto a 6-arcsec pixel scale add the following to the `_ITERATIVE_GROUP_PRODUCTION_` line: `SPREAD=gauss PARAM1=9 PARAM2=6 PIXSIZE=6`. The `PARAM2` variable determines the distance over which the gaussian has influence (6-arcsec in this example). The default regrid method is `NEAREST`. Smaller pixel sizes will clearly result in larger cubes on disk.

(HARP Mapping, continued from page 15)

2006). Other, more inclined, ridges can be identified at the top and bottom of the velocity range, along with Sgr A and Sgr B regions at *l*=0 deg and *l*=0.7 deg respectively.

This region of the Galactic Plane has been observed as part of the SCUBA Legacy Project and a comparison of this with the CO data clearly shows the CO closely tracing the continuum. At a wavelength of 868 microns the $^{12}CO(3\text{-}2)$ line falls within the bandpass of the 850 μm SCUBA/SCUBA-2 filter with the result that a fraction of the continuum flux may be attributed to contamination from the CO line. The degree of contamination varies from region to region but it has been calculated as contributing up to 50% of the flux in some cases (Hatchell et al. 2009, Zhu et al. 2003, Davis et al. 2000). SCUBA and HARP sample the same angular resoltuion (~15 arcsec) and we were able to use these combined datasets to calculate the contamination in this region.

We typically find relatvely low levels of contamination but this is heavily dependent on morphology and regions were identified where it exceeds 15%.

Figure 3 shows a 15×15 arcmin section of the co-incident SCUBA 850 μm map (Pierce-Price et al, 2000), overlaid with the $^{12}CO(3\text{-}2)$ contours from the HARP map. The blue markers indicate the positions of SCUBA cores as defined in the SCUBA Legacy Catalogue. This particular region highlights some interesting features; the two strong SCUBA cores in the frame have no associated CO emission; instead the CO, which is mostly diffuse, peaks approximately 1.5 arcmin inside of the cores. Comparison with UKIRT NIR data shows that the continuum emission coincides exactly with an infrared-dark cloud, dark that is except for a single bright nebula which peaks at the position of the lower SCUBA core.

The CLUMPFIND algorithm was used on the HARP map and the positions of the SCUBA and $^{12}CO(3\text{-}2)$ cores were compared using Topcat. Of the 2042 SCUBA cores that lay within the region of the HARP map, 1401 SCUBA cores had coincident ^{12}CO emission while 641 cores did not. The histogram of the flux of the two sets of SCUBA cores is shown in Figure 4. The median flux of the SCUBA cores with HARP counterparts was 2.94 Jy while those without was 1.26 Jy, this difference suggests potential populations of SCUBA cores at different evolutionary stages.

The ^{12}CO molecule was chosen for this test purely due to its strength and abundance but it also has considerable scientific merit. Apart from being crucial to determining accurate continuum fluxes, and subsequently masses, can be used to provide information regarding large-scale velocity dispersions as well as being a key tracer of molecular outflows. The 3-2 transition traces the medium density, warm gas associated with regions of high-mass star formation, material which may prove critical to our understanding of the mechanisms involved, from density profiles within molecular clouds to the role of turbulence in core formation.

Current observing strategies are leaning more and more towards large scale surveys which will pro-

(HARP Mapping, continued on page 17)

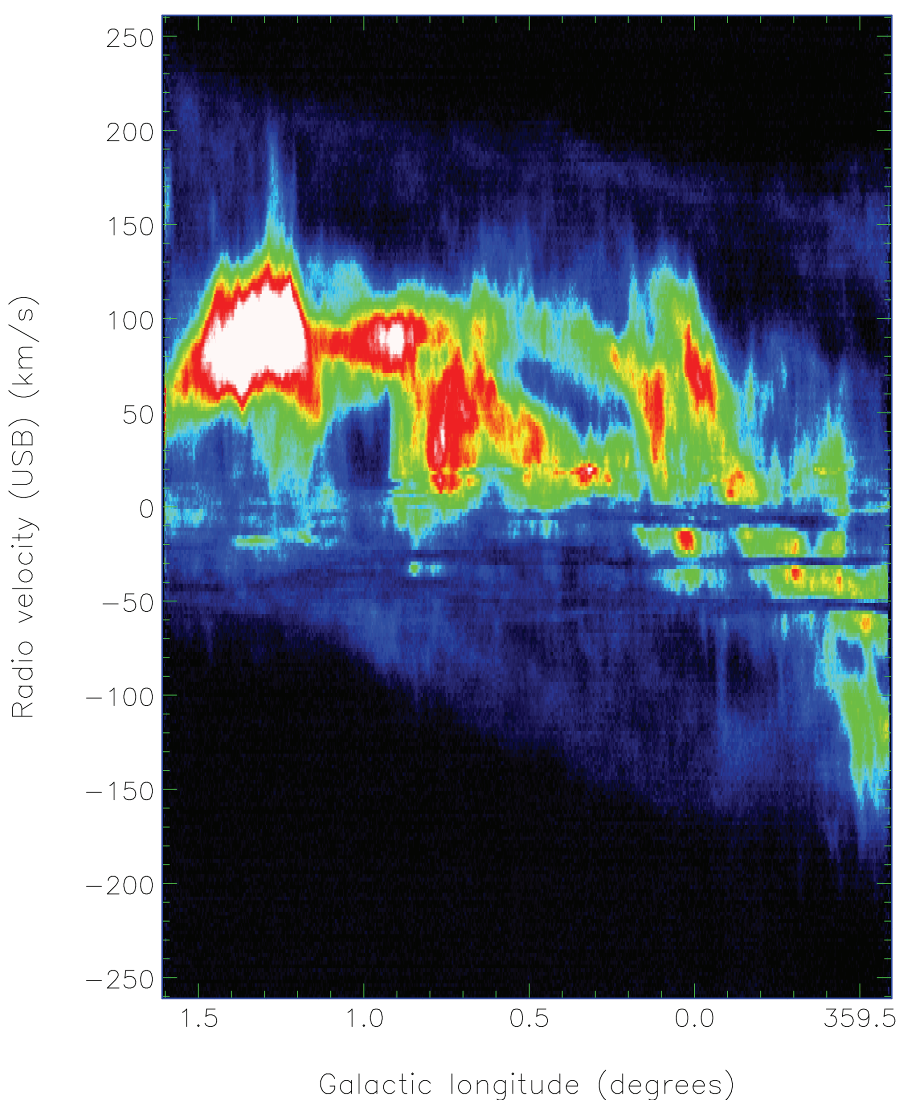


Figure 2. — The longitude-velocity plot of the region after collapsing through the entire latitude range of the map. The horizontal absorption features seem in the velocity range −55 km/s < v(LSR) < +20 km/s are the foreground spiral arms.

(HARP Mapping, continued from page 16)

vide legacy data and the robust statistics needed to properly study processes such as massive star formation. With surveys such as the JCMT Galactic Plane Survey and the Herschel Galactic Plane survey in the pipeline (so to speak), large-scale mapping with HARP may prove crucial for accurately interpreting this data. This test map has shown what can be achieved with the fast-mapping speed of HARP/ACSIS and the sensitivity that can be reached with HARP in relatively poor weather. HARP has proven to be far more flexible than previously considered and has shown its potential for large-scale mapping at faster speeds than ever before.

References

Davis, Dent, Matthews, Coulson, McCaughrean, 2000, MNRAS, 318, 952.

Di Francesco, Johnstone, Kirk, MacKenzie, & Ledwosinska, 2008, ApJS, 175, 241.

Hatchell & Dunham, 2009, A&A, 502, 139.

Oka, Hasegawa, Sato, Tsuboi & Miyazaki, 1998, ApJS, 118, 455.

Pierce-Price et al., 2000, ApJL, 545, 121.

Sofue, 2006, PASJ, 58, 335.

Zhu, Seaquist, & Nario, 2003, ApJ, 588, 243.

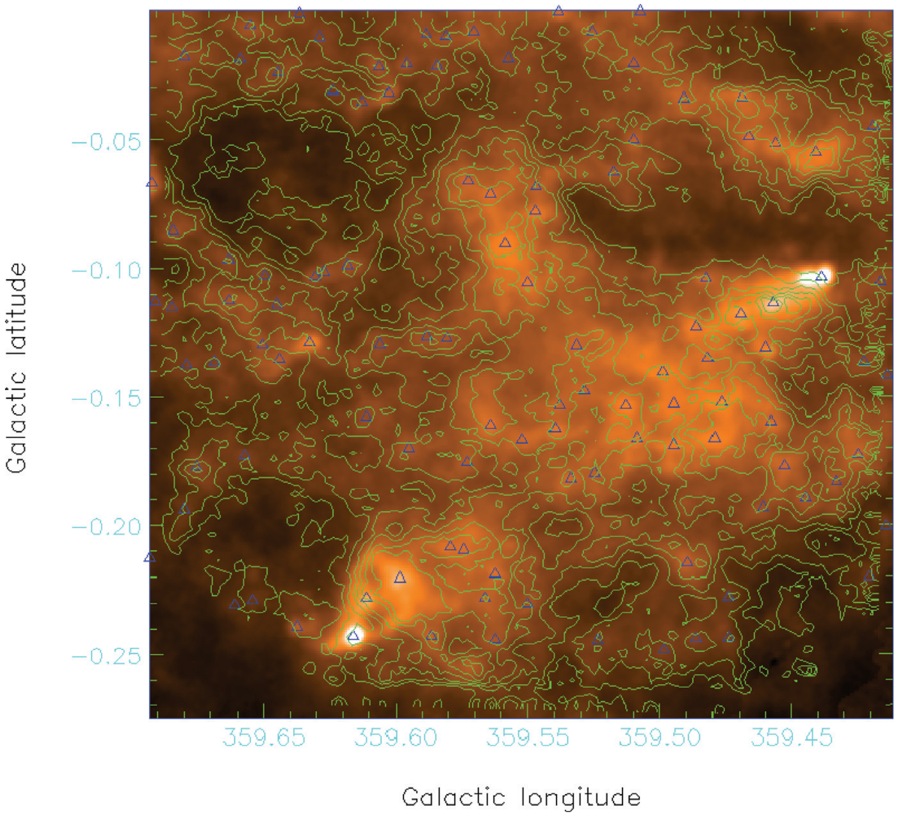


Figure 3. — Section of the Galactic Centre map from Figure 1. SCUBA 850 μm colour map with HARP $^{12}CO(3–2)$ contours. The triangles mark the positions of the SCUBA cores identified in the SCUBA Legacy Catalogue.

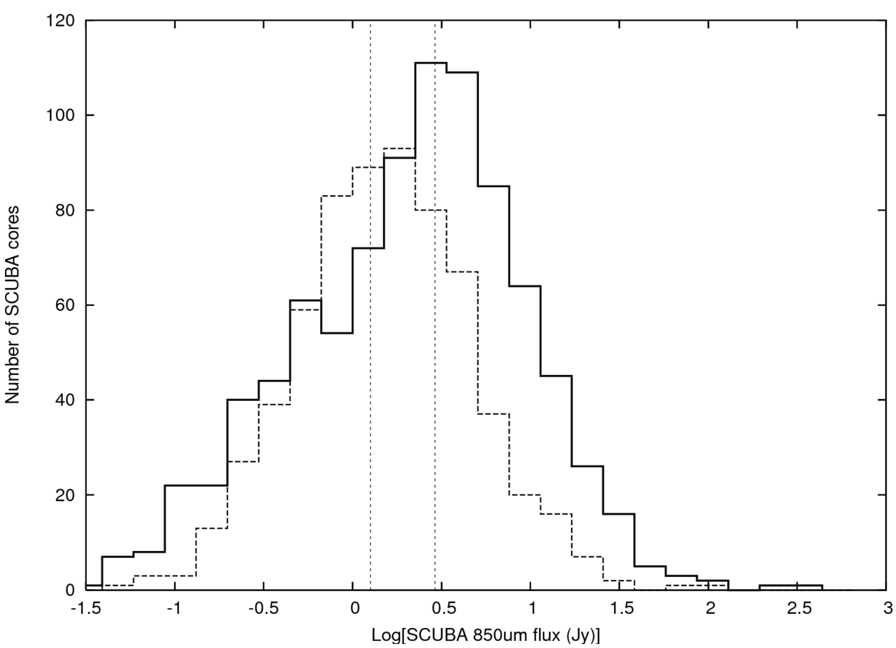


Figure 4. — Comparative distribution of 850 μm flux (Jy) for SCUBA cores with an associated CO core (solid line) and SCUBA cores without a ^{12}CO counterpart (dashed).

Galileo Block Party

Inge Heyer (*JAC Public Information Officer*)

As many readers know, 2009 is the International Year of Astronomy (IYA). On Saturday, October 24, the observatories on Mauna Kea in Hawaii organized the Galileo Block Party in Hilo. Many of JAC's UKIRT and JCMT staff participated. The Galileo Block Party was organized by the Mauna Kea Observatories Outreach Committee (MKOOC) for the entire Big Island community. A few thousand people were in attendance.

Opening ceremonies began in the early afternoon on the steps of the Subaru base facility with addresses by County of Hawaii Mayor Billy Kenoi, University of Hawaii at Hilo Chancellor Rose Tseng, and several others. Throughout the afternoon, local school bands performed, and even Galileo Galilei himself made an appearance.

During the afternoon there were activities at each of the observatory base facilities. For JAC, these included an extremely popular asteroid target practice game, a "guess the number of stars in a WFCAM image (of the Galactic centre)" challenge, an astronomy quiz, the birthday stars game, a Celestia demo, a comet demo, an asteroid impact demo, sorting the solar system, and various crafts (making comets and stars).

The other participating observatories also had many family-oriented fun activities. Participants also included the Hilo Astronomy Club, the University Astrophysics Club, Mauna Kea Support Services, the Office of Mauna Kea Management, and the 'Imiloa Astronomy Center of Hawaii.

More details on this event can be seen at http://www.naoj.org/IYA/Blockparty/ .

Figure 1. — The Galileo Block Party event poster.

Figure 2. — Michele Mulkey and Mila Chrysostomou (right) help kids make their own comet at the Galileo Block Party.

Figure 3. — Gary Davis, Mira Chrysostomou (right), and Connie Larsen (seated) keep score with the Asteroid Target Practice game.

Figure 4. — Marjorie Dougherty and (behind Marge) Caroline Davis making stars at the Galileo Block Party.

Mark Horita: 1958–2009

Gary Davis (*Director JAC*)

Mark Horita died in his sleep on the morning of 11 August 2009. He had been employed at the JAC for nearly 25 years — in fact it wasn't even called the JAC when he was hired because the JCMT had not yet been built — and in that time he had seen just about everything, and had met just about everyone, on both JAC telescopes. His passing at the age of 51 came as a shock to us all.

Mark was a mechanical technician for many years, and over the course of his time at the JAC he did a little bit of everything. When I arrived as Director in 2002 one of Mark's primary duties was to look after the gas handling system for SCUBA's dilution refrigerator, and when the system deteriorated badly in 2004 it was brought down to Hilo for a thorough overhaul. Mark spent days and days in the laboratory, diligently cleaning, repairing or replacing every single connection in the system whilst the astronomers on staff waited anxiously for SCUBA to be returned to service. I've diagnosed more vacuum leaks in my life than I care to remember, but I don't think I would have had the patience for that particularly daunting job.

When Mark was diagnosed with back trouble in 2004 which prevented him from working at the summit, his job duties were altered. Many readers might be unaware that the engineering and technical staff who spend most of their time looking after UKIRT and the JCMT also maintain the JAC building in Hilo. These duties were re-arranged within the group such that Mark took over the lion's share of the Hilo-based work. He also provided logistical support for activities at the summit. During the SCUBA-2 infrastructure project in 2006, for example, Mark supervised the ferrying of materials and supplies up and down the mountain so that the summit crew could focus on the work at hand. His Hilo work included building maintenance, vehicle maintenance, maintaining inventory, and a thousand other odd jobs. In recognition of these new duties, he was given the title "Maintenance/Logistics Facilitator": a bit of a mouthful, to be sure, but over time he made the job his own and he became the go-to person at the JAC for any Hilo building issues.

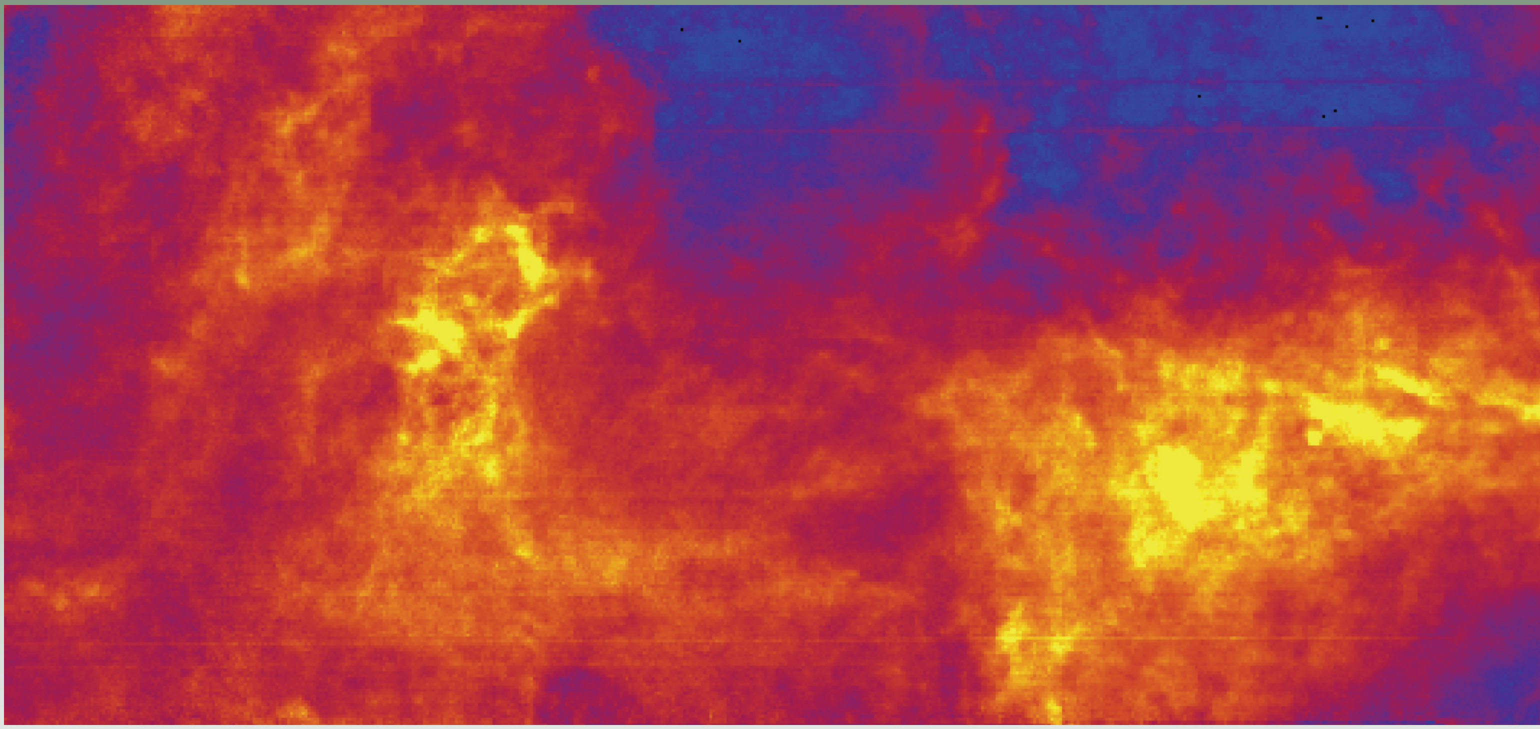
Mark was a local in every sense: he was born and raised right here in Hilo and lived here his entire life. In his spare time he was a keen hunter, but his overwhelming passion was for food, and it was a passion he loved to share. He was frequently to be found in the Phase II corridor distributing samples of his latest concoctions, and occasionally he would even wander further afield to offer Hawaiian delicacies to the uninitiated non-island staff. I well remember one occasion when I brought 18 "loco moco"s into work one morning to thank the engineering staff after a long and arduous campaign on the mountain: Mark's eyes lit up with delight and he immediately went to the fridge to extract his personal supply of special-blend hot sauce, which he promptly offered to everyone around the table.

Mark's sudden death was a blow for his friends at the JAC. Readers who knew him will, I am sure, echo my condolences to his family.

JCMT Science Archive Update | *New Starlink Software Collection Release*

Galactic Centre

HARP $^{12}CO(3-2)$ mapping



www.jach.hawaii.edu/JCMT