JCMT NEWSLETTER

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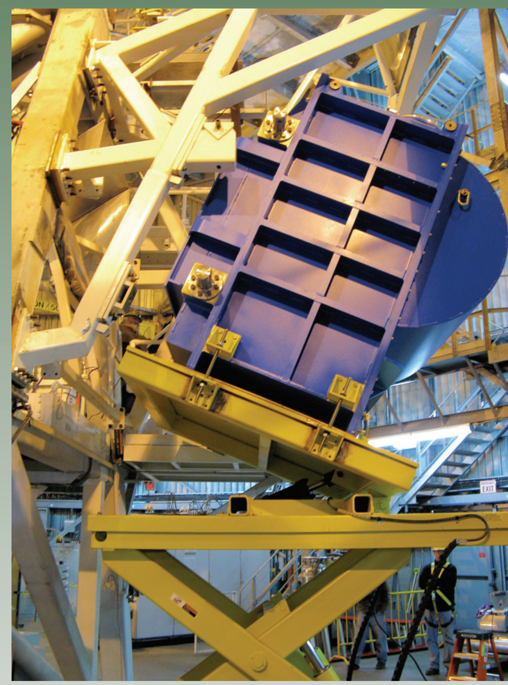


SCUBA-2

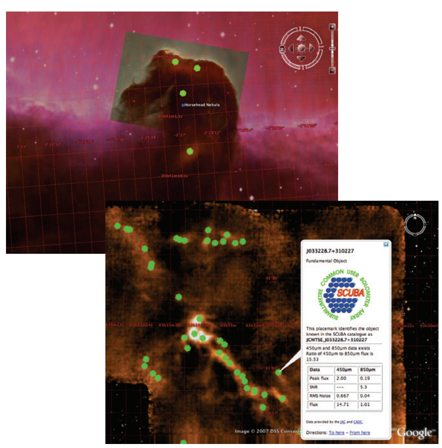
installation and integration begin

HARP/ACSIS Science Results

Planetary Spectroscopy Results

In This Issue

On the front cover: SCUBA-2 installation and integration at JCMT. (Also see articles on pages 3 and 14 of this issue; images courtesy Jonathan Kemp/JAC and Jim Hoge/JAC.)



On the rear cover: Google Sky offers SCUBA point sources and images as a complement to its optical images. (Also see Figures 1 and 2 and article on page 9 of this issue.)

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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

SCUBA-2 is in the building! We have been anticipating the arrival of this revolutionary instrument for so long now that it is almost difficult to believe that it has finally arrived. As we write this column, a team from the UK ATC is in Hawaii, working closely with JAC engineering staff to get the instrument installed and integrated into the observatory operating environment. The arrival of the instrument has galvanised everyone involved and it is a very exciting time at the JCMT.

SCUBA-2 was delivered with two commissioning-grade arrays, one at each wavelength (450 & 850 μm): they do not meet the science-grade specification, but they are of sufficient quality for the astronomical commissioning of the instrument to proceed. A set of science-grade arrays is scheduled for delivery in late 2008, leading to science operations with the full instrument in early 2009. We plan to offer SCUBA-2 to the community on a shared-risk basis with the two commissioning-grade arrays in late 2008.

Another important milestone for the observatory and its community was reached in winter 2007: the much-anticipated commencement of the JCMT Legacy Survey. Three teams (Spectral Legacy Survey, Gould Belt Survey and the Nearby Galaxies Survey) began collecting data for their surveys using HARP. In the main, the data have been of excellent quality and some of the early results have proved to be quite exciting, and we hope to read more from the teams on these results within these pages soon. You can keep up with general survey progress on the JLS Status page (`http://www.jach.hawaii.edu/JCMT/surveys/JLS_status.html`).

Although we are all excited by the arrival of SCUBA-2, the reports we receive from visiting observers and the science results we see from HARP/ACSIS are proving that this particular instrument combination is a powerful one, something which is clearly demonstrated by the variety of science reported in this issue. There are still some minor issues with the instruments which continue to frustrate us, as is normal with any new instrument and particularly those which push the observatory into uncharted territory, but the resolve, dedication and ethic of the JAC engineering, software and science groups give us confidence that these problems will eventually be resolved.

Progress with the JCMT Science Archive (JSA) continues at a steady pace. You should all now be downloading your data from our archive at the CADC either directly or via your project pages on the OMP. Gridded cubes have been available for a while, and baselined cubes, using a baseline removal procedure developed in-house, will begin to roll out in the next few weeks. Of course, in the background to this there has been a tremendous amount of technical development and progress on the JSA infrastructure, at both the CADC and JAC sites, which enable and prepare this facility for the next significant stage of this project: implementation and delivery of Advanced Data Products.

We have reported previously that all three agencies had indicated their intention to continue operating the JCMT for some years beyond 2009, the year in which the tripartite agreement contains a break point. This remains the case, although the agencies have not as yet been able to commit signatures to paper. The situation in the UK has been particularly difficult, with the well-documented financial difficulties of the STFC limiting the organisation's ability to make any firm commitments. We were very pleased to note, however, that the JCMT was ranked in the top-priority category by the STFC Programmatic Review, making it a "must-do" project. This is entirely fitting since the JCMT remains the world's premier facility for submillimetre astronomy: a review of observatory productivity last year by Trimble & Ceja (*Astron. Nachr.* 328, 983, 2007) ranked the JCMT first amongst submm/mm facilities by a very wide margin.

Antonio Chrysostomou, Associate Director JCMT

Finally, there have been two staffing changes since the previous newsletter which will be of interest to JCMT observers. First, the JAC receptionist Sharlene Hamamoto resigned in February to take a position on O'ahu. This change represents a good career advancement opportunity for Shar and we wish her well, but we will miss her smiling face at the front desk and her efficient maintenance of the vehicle schedule. Second, the JCMT secretary Donna DeLorm retired in February after more than 22 years at the JAC. Users will be familiar with Donna because she looked after accommodation bookings and a host of other details for visiting observers. We will miss her, both as a friend and as a colleague. At the same time, though, we welcome the new JCMT secretary, Linda Gregoire. Linda is Canadian by birth but she has lived in Hilo for the past several years and she brings a wealth of experience to the position. Please pop in to say hello on your next visit to the JAC.

Heavy Water in Solar-Type Protostars

Cecilia Ceccarelli (*LAOG*), Steven Charnley (*NASA Ames*), & Harold Butner (*James Madison*)

One of the last few years' discoveries is what is now referred as the "super-deuteration" phenomenon, namely a huge increase of abundance of D-bearing compared to H-bearing isotopologues in trace molecules. This phenomenon is observed in regions of low mass star formation, notably in pre-stellar cores and in the youngest sources, the Class 0 sources (see the review in, *e.g.*, Ceccarelli *et al.* 2007). So far the most spectacular values have been found in molecules like formaldehyde (H_2CO), methanol (CH_3OH) and ammonia (NH_3), where the doubly and even triply deuterated isotopologues have been detected with abundances of more than 1% (Ceccarelli *et al.* 1998; Parise *et al.* 2004; van der Tak *et al.* 2002). Given that the elemental D/H ratio is ~2×10^{-5} (Lynsky *et al.* 2005), if the D and H atoms were distributed statistically, the abundance of the triply deuterated methanol should be more than 13 orders of magnitude lower than observed!

It has been long known that the deuteration in molecular clouds is due to the reaction of neutral molecules with the deuterated molecular ion of H_3^+, H_2D^+, that "transfers" the D atoms from the main deuterium reservoir, HD, to the trace molecules (*e.g.*, Watson 1976). Only recently it has been recognized that in extreme conditions, the other H_3^+ isotopologues, HD_2^+ and D_3^+ also play an important, if not a major role in this reaction, giving rise to super-deuteration (Caselli *et al.* 2003; Roberts *et al.* 2003; Vastel *et al.* 2004). These extreme conditions occur during the coldest phases of solar type star formation, because of three simultaneous circumstances: 1) the low temperature of the gas; 2) the low electronic abundance; and, 3) the freezing-out of the CO molecules onto the grain mantles.

Water, however, seems to follow a different fate. Observations in the IR have so far failed to detect deuterated water in the solid state, at an upper limit of about 2% (*e.g.*, Parise *et al.* 2003). In the gas phase, Parise *et al.* (2005) have measured as little as 3% of HDO with respect to H_2O in the region where ices are sublimated towards the solar type protostar IRAS 16293-2422 (Parise *et al.* 2005). When compared to the abundances of the singly deuterated isotopologues of formaldehyde (HDCO) and methanol (CH_2DCO), that constitute more than 1/3 of the total molecules' abundance, the singly deuterated water is a sound factor ten lower. There may be several reasons for this difference of behavior, including the fact that the abundance of water may be so large that it may compete for the main reservoir of the deuterium atoms.

One has to emphasize that water is not "just another molecule in the zoo of deuterated molecules"; the degree of water deuteration is one of the claimed hallmarks for the exogenetic origin of the terrestrial oceans. For this reason, understanding the route of water deuteration is particularly and specifically important. For this reason we have carried out observations at JCMT of the ground transition of doubly deuterated water (D_2O), at 316.8 GHz.

After a long integration of about 8 hr, and after verifying the detection with observations taken at CSO with a lower spectral resolution, we finally detected the line. The observed line spectrum is reported in Figure 1. It shows an emission component, whose linewidth is 6 km/s, and an absorption dip, whose linewidth is 0.5 km/s. In the same figure we also show the line spectrum of the HDO ground transition at 464 GHz, that was previously observed at JCMT (Parise *et al.* 2005). Based on the comparison between the two lines and arguments related to the radiative transfer of the D_2O line, we concluded that both the D_2O emission and absorption arise in the hot corino region, namely the region where the ices sublimate because the dust temperature reaches 100 K. The reader can find the full discussion of the analysis in Butner *et al.* 2007.

The detected D_2O line allows us to estimate the D_2O abundance, found to be about 1.7×10^{-10} with respect to

(Heavy Water, continued on page 5)

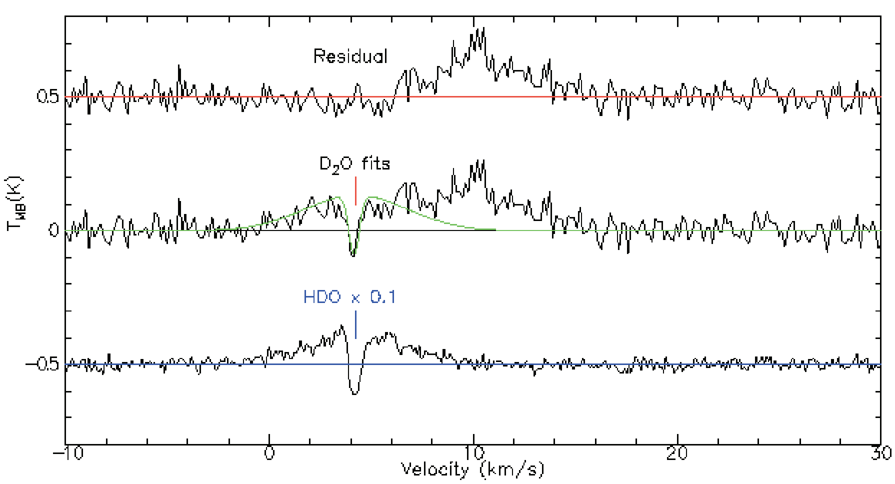

Figure 1. — The 1_{10}–1_{01} transition of para-D_2O at 316.7998 GHz detected in emission and in absorption towards IRAS 16293-2422 (center). A two-gaussian component fit (green), using the velocity width and V_{LSR} of the HDO line is superimposed on the D_2O spectrum. This HDO line (scaled by ×0.1) is shown at bottom. On top, an emission component is evident in the residual spectra obtained after the D_2O gaussians have been subtracted, likely due to CH_3OD. See Butner et al. (2007) for a full discussion.

Evidence of Large-Scale Outflows in the Serpens South Cluster

Brenda Matthews (*NRC/HIA*), Robert Gutermuth, Tyler Bourke, Lori Allen (*Harvard-Smithsonian*), Mike Dunham, Neal Evans, Paul Harvey (*Texas*), Jennifer Hatchell (*Exeter*), & Jes Jørgensen (*MPI Bonn*)

The Serpens South Cluster is a recently identified region of very active, clustered star formation discovered by the Spitzer Gould Belt Legacy Survey team (see Gutermuth *et al.* 2008, ApJ, 673, 151). Located ~3 degrees south of the well-studied "Serpens Main Core" and at a distance of 260±37 pc from the Sun, the SSC contains at least 91 young stellar objects, 59% of which are protostars, with a stellar density higher than that of the SMC. The mean surface density in the central 2.5 arcmin (0.2 pc) of the cluster is 430 pc^{-2} with a median projected separation of 3700 AU. Within the Serpens Main Core, the median nearest neighbour distances are much larger 4800 AU, reflecting the fact that the cluster is more diffuse. These conclusions are based on IRAC data at 3.5, 4.5, 5.8 and 8 μm combined with 2MASS data as published by Gutermuth *et al.* The IRAC wavebands are not sensitive to the youngest phase of protostellar evolution. Therefore, the surface densities inferred from the Spitzer and 2MASS data are certainly underestimates to the total population of the cluster.

In addition to a young population of protostars, the Spitzer images reveal an extensive filamentary structure seen in extinction. In order to probe the gas content of the region arising from the filament itself and outflows associated with the YSO population, we have used HARP to map the ^{12}CO (3–2) emission from the centre of the region, and extensive outflows are revealed. The blue-shifted emission is dominant, delineating several collimated outflows to the southwest of the cluster. The red-shifted emission is weaker and more diffuse. For instance, the counterpart to the strong western blue-shifted lobe is not seen in the integrated intensity map in Figure 1. Interestingly, the ^{12}CO(3–2) emission seems to be entirely self-absorbed toward the region with no emission at the systemic velocity of ~9 km/s. More observations to expand the map to the southeast and northwest along the filament are in the queue for semester 08A.

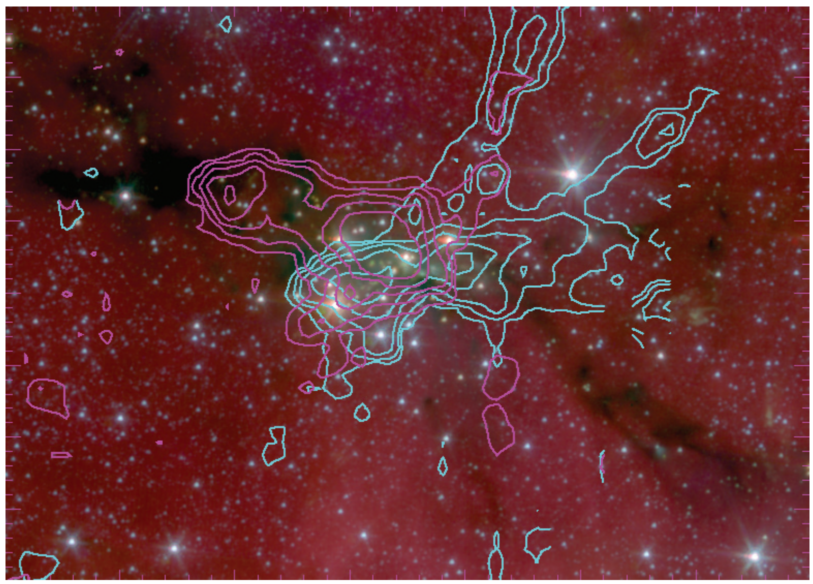

Figure 1. — Spitzer false colour image of some of the filamentary dark cloud structure seen in the Serpens South Cluster. Superimposed are contours of red-shifted and blue-shifted CO emission detected with HARP. North is to the left; east is down.

(Heavy Water, continued from page 4)

H_2, and the ratio with respect both H_2O and HDO: $D_2O/HDO=1.7\times10^{-3}$ and $D_2O/H_2O=5\times10^{-5}$. Compare that with $D_2CO/H_2CO=0.1$ and $CHD_2OH/CH_3OH=0.3$ in the same source; water is definitively a peculiar case!

In Butner *et al.* (2007), we carefully examined the possible routes of water formation and tried to understand if the measured D_2O abundance can shed some light on this mystery. We concluded that shock chemistry can be ruled out as contributing to the origin of the water in this source. At steady-state, grain-surface chemistry and ion-molecule reactions both predict D_2O/HDO ratios ≈4–5 times higher than observed. However, in the latter case, lower D_2O/HDO ratios are possible if the gas-phase chemistry of water and its deuterated isotopologues did not attain a chemical steady-state prior to most of the molecules condensing on to dust grains. This scenario is also consistent with the low fractional abundance of water measured in IRAS 16293-2422, and is generally consistent with rapid molecular cloud formation and protostellar evolution (Di Francesco *et al.* 2007; Ceccarelli *et al.* 2007). Even though we were unable to give a definitive answer, the D_2O detection has helped to rule out some old hypotheses and to formulate new precise ones.

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Sulfur in the Venus Mesosphere

Brad Sandor, Todd Clancy (*Space Science Institute*), & Gerald Moriarty-Schieven (*JAC/HIA*)

The thick cloud layer obscuring Venus' surface, and presenting the planet as a high-albedo, nearly featureless cue ball, is primarily composed of sulfuric acid (H_2SO_4) aerosol. For these most famous (and many lesser known) reasons, atmospheric sulfur is crucially important to Venus, and of great scientific interest. Its complex behavior involves gas-phase chemistry, solution chemistry (*e.g.*, sulfuric acid dissolves in water droplets), phase changes of sulfur (*e,g.*, dry sulfuric acid exists both as a gas, and as a solid aerosol), and atmospheric dynamics.

Sulfur behavior above the clouds, above 60 km, was largely unknown before targeted studies from the JCMT began. Above the clouds and prior to JCMT observations, SO and SO_2 had been measured at 60–70 km, with IR and UV data that had no sensitivity to higher altitudes. In contrast, submm absorption lines measured with the JCMT are specifically sensitive to sulfur at altitudes 70–100 km. The importance of the earlier 60–70 km IR and UV data should not be minimized. However, submm findings at 70–100 km reveal behaviors unlike anything seen below 70 km. Further, JCMT measurements of SO and SO_2 contradict photochemical modeling results that had previously been unquestioned.

Submm studies yielded a first detection of 70–100 km SO_2 in 2004, and subsequent observations are bringing many surprises. Sulfur behavior over the entire observed hemisphere is highly variable. On Jan 14, 2007, we obtained the first 70–100 km SO detection. Then our Jan 20 measurement showed SO abundance had tripled in only six days, and over the entire visible hemisphere (Figure 1). Other observations demonstrate SO_2 abundance also changes rapidly on one-week timescales.

Proximity (130 MHz separation) of the strongest B-band SO and SO_2 lines allows us to always observe them simultaneously. In figure 2 our April 7 (dayside) and August 7 (nightside) spectra are overplotted. The diurnal pattern, stronger SO than SO_2 absorption on the dayside, and stronger SO_2 than SO absorption on the nightside is not contradicted in any of our data. However, there are observation dates when absorptions of both SO and SO_2 are <0.1%, *i.e.*, neither molecule is detected, and no determination of their relative absorption strengths is possible. (While comparison of SO and SO_2 in absorption units is illustrative, the SO line is spectroscopically stronger. Mixing ratio of SO is smaller than that of SO_2 in all our observations.)

Spectra such as those in figure 2 tell us mixing ratios of SO_2 and of SO increase with altitude. JCMT sensitivities to the 70–85 km and 85–100 km regions are very similar, and altitude resolution is derived from pressure broadening of submm lines.

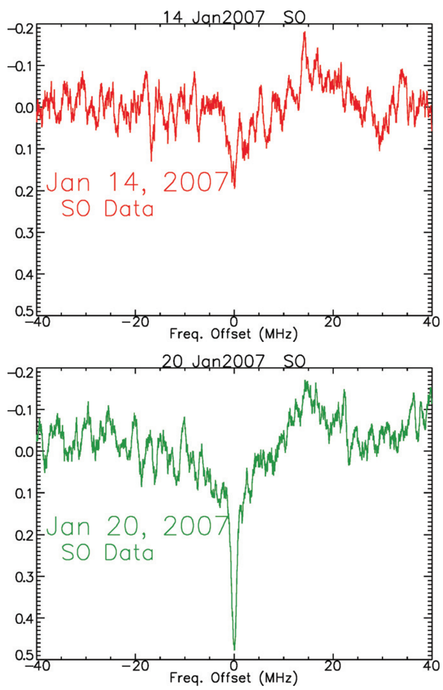

Figure 1. — Sulfur monoxide (SO) absorption spectra toward Venus, taken on 14 January and 20 January 2007. Note the 3× increase in absorption of SO in 6 days!

The narrow absorption lines we observe indicate SO_2 and SO are each confined above 85 km. Figure 2 data are well fit by a 2-layer model in which SO_2 abundance is 130±10 parts per billion (ppbv) at 85–100 km, and 0.±10 ppbv at 70–85 km. The data cannot be fit by a 1-layer model of SO_2 constant over 70–100 km. All our SO_2 and SO absorption lines are similarly narrow, and can only be produced if the absorbing molecule is confined above 85 km.

This discovery, that SO_2 and SO abundances increase with altitude, contradicts all photochemical model predictions, and overturns what had been conventional wisdom. Chemical modeling had predicted SO_2 and SO would each decrease rapidly with altitude, the opposite of what we observe. Conventional wisdom had reasoned that SO_2 and SO are each rapidly photolyzed by sunlight, and should therefore decrease with altitude. Observations show that Venus sulfur behavior is far more complicated. The Venus modelling community is struggling to interpret and understand our measurements, while we plan future observations to address questions raised by our data in hand.

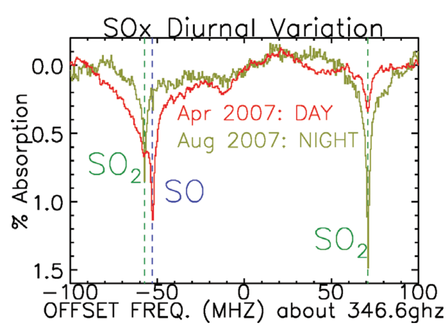

Figure 2. — SO/SO_2 absorption spectra toward Venus, taken April 2007 (when Venus was near superior conjunction, i.e., showing the daytime hemisphere) and August 2007 (near inferior conjunction, i.e., nighttime hemisphere). Note that SO appears to dominate the day side, while SO_2 dominates the night side.

Acid Water in Colliding Galaxies

Floris van der Tak (*SRON Groningen*)

Our Galaxy is currently going through a quiet phase of its life, as do most of the roughly one hundred billion other galaxies in the Universe. But at any given time, a few galaxies go through a restless, active phase, where they emit over a thousand times more light than normal galaxies do. The extra radiation originates in the nuclei of active galaxies, which totally outshine the galaxies' outskirts. The origin of this sudden activity is usually a collision between two normal galaxies. Such collisions happen quite often in space, with the Antenna galaxies (NGC 4038/NGC 4039) as famous example. The result of a galactic collision may be a burst of star formation, or the formation of a supermassive black hole (millions of times heavier than the Sun). Astronomers observe both these processes in colliding galaxies, but they are not sure if they exclude each other or if, for instance, one precedes the other. Since these processes are fundamental to the evolution of the universe, astronomers would like to peer into the nuclei of colliding galaxies as deeply as possible. In most cases, studying these nuclei is quite hard, because thick clouds of gas and dust block the view like a smoke screen – at least to our eyes. But like a pilot is able to land in fog thanks to radar, astronomers can use long-wavelength telescopes (infrared or radio waves) to look deeper into the nuclei of galaxies than in visible light. The submillimetre part of the spectrum is particularly suited to the study of conditions in the nuclei of colliding galaxies, because it is in this waveband where many molecules emit radiation. For example, CO has an emission peak near 345 GHz and water near 557 GHz. Using submillimetre spectra, astronomers are thus able to tell the existence of certain molecules in clouds at thousands or (with large telescopes) millions of light years from Earth. This information is valuable because the chemical composition of a gas cloud contains many clues to the future of the cloud. The reason is that certain molecules occur preferentially in warm clouds, others predominantly in clouds at high pressure, and again others in the presence of ultraviolet radiation. And these basic properties of clouds — temperature, pressure and radiation field — determine whether the cloud is stable or will evaporate, or whether it will collapse to form stars.

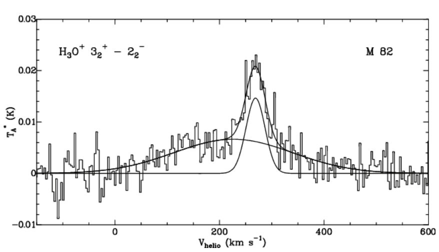

Figure 1. — Spectrum of H_3O^+ toward the nucleus of M 82. The spectrum is best fit by two components, a narrow line likely from the eastern molecular peak of M 82, and a broad line coming either from more widely distributed molecular gas, or from the nucleus.

The particles in a gas cloud attract each other through gravity, and in the absence of other forces, the cloud will shrink until the particles are so close together that stars form. In galaxies however, large-scale magnetic fields occur which pervade the gas clouds. The particles in the clouds thus feel a magnetic force which tends to bind them to the field lines and keeps them from falling toward the cloud center. The magnetic force only acts on charged particles, though. How effectively the magnetic field may counteract gravity and prevent the formation of new stars thus depends on how strongly charged the cloud is. Astronomers thus would like to know the prevalence of charged particles in gas clouds.

In April 2007, I have used the HARP instrument, then newly commissioned on the JCMT, to discover the H_3O^+ (hydronium) molecule in the nuclei of two nearby galaxies. This is the first result obtained with the HARP instrument which is published in a refereed journal! Although its name may sound exotic to some readers, H_3O^+ occurs naturally in liquid water on Earth, and its concentration determines the acidity of the water. Hydronium in gas clouds in space emits radiation at submillimetre wavelengths, most of which is blocked by the atmosphere of the Earth. With special telescopes such as the JCMT, located on a high and dry site, astronomers are able to measure this radiation — if the weather cooperates. In this case, good weather means that the air contains very little water vapour, and therefore: the colder, the better. My family always looks funny at me when I pack a thick sweater in my suitcase for Hawaii!

The astronomical importance of this discovery lies in the fact that the amount of H_3O^+ is a measure of the total number of charged particles in a cloud. The more free protons are around, the more will bind to an H_2O molecule. In the two galaxies that I observed, the number of charged particles appears to be large enough that magnetic fields will be able to significantly reduce the rate of star formation. Ironically, at least in the case of M 82, it is the young stars themselves that cause the ionization of the gas clouds: the process of star formation is counteracting itself. In the case of Arp 220 on the other hand, X-rays from the central supermassive black hole seem the most likely origin of the ionization.

In the next For more information, please see *A&A*, 477, L5 (2008). This work was done in collaboration with Susanne Aalto (Onsala) and Rowin Meijerink (Berkeley).

Star Formation at the Edge of the Galaxy

Jan Brand (*INAF IRA*) & Jan Wouterloot (*JAC*)

Star formation is very prominent in the inner regions of the Galaxy, especially at the Galactic Centre and in the molecular ring at galactocentric distances $R \approx 4$–6 kpc. Evidently the conditions there for the formation of stars from molecular material are very favourable. The physical conditions of the interstellar medium in the Galaxy change with distance from the Galactic Centre, and the far-outer Galaxy (which we define here to be at $R \geq 16$ kpc) presents quite a different environment from that in the inner Galaxy.

These changes might be expected to influence the formation of molecular clouds and the star formation process within them. Indeed, while the galactic atomic hydrogen disk has a radius of at least 25 kpc, molecular clouds are found only out to about 20 kpc. The surface density of the molecular disk at that point is only $\sim 10^{-2}$ $M_{\odot}$ pc^{-2} (the H I reaches this level at $R \sim 50$ kpc). The formation of molecular clouds from atomic clouds at large R is made more difficult by the continuously decreasing surface density and the increasing scale-height and the consequent decrease of volume density of the gaseous disk. This is exacerbated by a decrease in metal abundance and dust by a factor of 10, hence by a decrease of H_2 formation sites.

Nevertheless star formation *is* occurring out to large distances from the Galactic Centre. Star formation indicators such as the detection rate of water masers, the number of H II regions per unit mass of H_2, and the number of bright FIR sources per H II region indicate that once molecular clouds are formed, there is no difference between star-forming activity near the Sun or in the Perseus arm and in the outer Galaxy.

As part of our long-term study of molecular clouds and star formation in the outer Galaxy, we recently completed our study of the star forming region associated with IRAS 06145+145 (WB89-789; Wouterloot & Brand 1989, *A&AS*, 80, 149). This object is located in the anti-centre direction (l,b = 195.82 deg, −0.57 deg). The kinematic distance of its associated molecular cloud is 11.9 kpc, and it is located at $R \approx 20.2$ kpc, at the edge of the (molecular) disk of the Galaxy.

Star Cluster

We observed the region around the IRAS source with the ESO 2.2-m telescope in the NIR (J, H, and K-bands). These observations revealed a compact cluster embedded in the molecular cloud. A false-colour image is shown in Figure 1, left. Analysis of the star density reveals the presence of a cluster consisting of about 60 stars, with a radius of 1.3 pc. From a [J–H] vs. [H–K] colour-colour diagram we find at least 14 stars with NIR-excess, indicative of the presence of circumstellar dust and hence of very young objects. Three of these are possibly Class I objects. The youth of this region is corroborated by the detection of an H_2O maser and the *non*-detection of radio continuum emission.

Molecular Cloud

The molecular cloud associated with the cluster has been extensively observed in mm-lines and mm-continuum. Most observations were carried out at the JCMT, although we also used the IRAM 30-m and the SEST. The JCMT ^{13}CO and C^{18}O J=2–1 and IRAM CS J=2–1, 3–2, 5–4 observations show that the cluster is embedded in a ~500–1500 $M_{\odot}$ (virial mass) core, of radius 1.1–2.7 pc (depending on the tracer). This core is contained in a $\sim 5 \times 10^3$ $M_{\odot}$ cloud of size 12.6×7.4 pc.

Molecular Outflow

In the molecular core in which the star cluster is embedded, an outflow is detected. Figure 1, right, shows the integrated ^{12}CO(3–2) emission. The total mass of the swept-up material is <~10 $M_{\odot}$. An interesting feature in Figure 1, right, is the presence of two extended features near offsets (+10 arcsec, −3 arcsec) and (−16 arcsec, +4 arcsec). These are brightest in K and virtually absent in J and can be easily recognized as the red spots in Figure 1, left. This emission might be due to the 2.1 μm line of H_2, a manifestation of the

(Star Formation, continued on page 9)

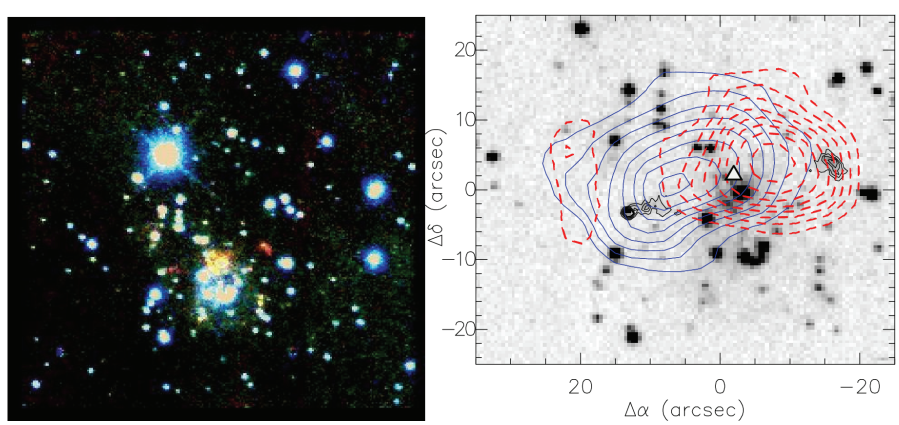

Figure 1. — (left) False colour image (J=blue, H=green, K=red) of a ~1.7 arcmin × ~1.7 arcmin region around WB89-789. (right) Map of the integrated ^{12}CO(3–2) wing emission (JCMT-data). Blue (drawn): 20<V_{lsr}<31.2 km/s; red (dashed): 37.2<V_{lsr}< 55 km/s. Lowest contour level and step are 2.0 K km/s. The IRAS position is at (0,0). The white triangle with black outline marks the position of the peak of the SCUBA 850 μm emission. The underlying image is the K-frame of the region. Contours are drawn to highlight two extended features near offsets (+10 arcsec, −3 arcsec) and (−16 arcsec, +4 arcsec) that might mark spots where the outflow impacts with the ambient medium. These spots are clearly visible as red blobs in the left panel.

SCUBA Data on Google Earth

Robert Simpson (*Cardiff*)

Google Earth is a free and cross-platform software package which enables users to fly around a 3D Earth, patchworked together from satellite and aerial photography. Last Summer, Google announced that Google Earth could now also become Google Sky (Scranton *et al.* 2007). In a similar fashion, users can explore the interior of a virtual celestial sphere. Google Sky is not made up of aerial photos, but of various star catalogues and sky surveys that are publicly available, *e.g.*, the DSS and many Hubble images.

In an effort to engage the public in submillimetre astronomy, I have made the SCUBA emission maps and the point source catalogue available on Google Sky in what is called a layer. The data are hosted by the CADC, who also host the complete public SCUBA catalogue of maps upon which this Google Sky layer is based (Di Francesco *et al.* 2007). It is now possible for anyone to access the SCUBA maps through Google Sky, simply by downloading the small 'layer' file.

Viewing the 850 and 450 μm continuum data on Google Sky means that anyone can begin to visualise what the submillimetre universe looks like in relation to other wavelengths and objects. The easy-to-use zoom and pan tools allow anyone to get a feel for the size and scope of the data available. An example is shown here in a screen capture from the application showing the Horsehead Nebula in both visual (Figure 1) and submm (Figure 2) bands (also see rear cover of this issue). You can see the line where the purple, optical image borders the normally invisible, orange 850 μm data.

The extended SCUBA point source catalogue is also included and these appear as green hexagons in the images here. This list provides for each object, in both 850 μm and 450μm bands where available, the respective maximum intensity, estimates of total flux and size, and tentative identifications from the SIMBAD Database. I have also added a short list of 'interesting' features for those not familiar with SCUBA.

Google Sky reads an open XML file format that allows anyone to create compatible data for display. Here the SCUBA catalogue FITS images have been converted into a format Google Sky can read and the relevant XML has been generated. The maps are designed to download to the user dynamically, saving download time and disk space.

To access the layer in Google Sky, you'll first need to have the latest version of Google Earth installed. Then download the XML file from the SCUBA Legacy page at CADC. All links are given below. The file should open and then take a moment to download some data before it begins.

The data layer should also appear soon in Google's own catalogue to maximise exposure to the public and to Google Sky users in general.

SCUBA Legacy Catalogues can be downloaded at `http://www.cadc.hia.nrc.gc.ca/community/scubalegacy/`; Google Earth at `http://earth.google.com/`.

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"The SCUBA Legacy Catalogue: Continuum Objects Detected by SCUBA", James Di Francesco, Doug Johnstone, Helen Kirk, Todd MacKenzie, Elizabeth Ledwosinska, 2007 (astro-ph/0801.2595).

"Sky in Google Earth: The Next Frontier in Astronomical Data Discovery and Visualization" ,Ryan Scranton, Andrew Connolly, Simon Krughoff, Jeremy Brewer, Alberto Conti, Carol Christian, Brian McLean, Craig Sosin, Greg Coombe, Paul Heckbert, 2007 (astro-ph/0709.0752).

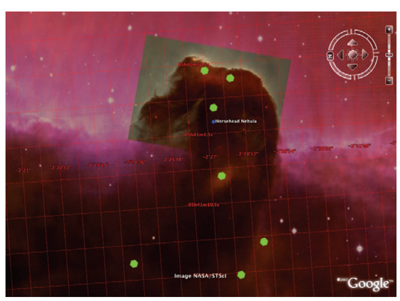

Figure 1. — Google Sky offers SCUBA point sources and images as a complement to its optical images. Here we see the Horsehead Nebula optical image (purple) with the SCUBA 850 μm image in orange. The green hexagons are SCUBA point sources. (Also see rear cover of this issue.)

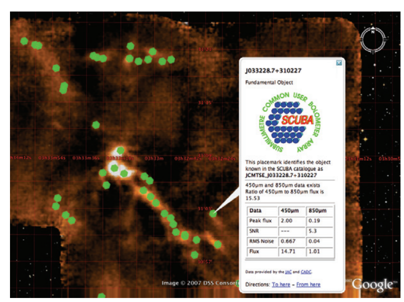

Figure 2. — Click on a green hexagon in this 850 μm image (of the HH 783 neighbourhood of the B1 molecular cloud) in Google Sky, and a popup appears with the name and submm properties of the selected source. (Also see rear cover of this issue.)

(Star Formation, continued from page 8)

interaction between the outflow and the ambient medium.

Distance

This embedded star cluster is located near the galactic anti-centre direction, where the determination of kinematic distances is notoriously uncertain because the radial velocity is not very sensitive to the distance, and random motions become relatively influential. In fact, a cloud-cloud velocity dispersion of ~5 km/s could allow a range in galactocentric distance of WB89-789 of 17–25 kpc. However, a spectrum taken of one of the members of the cluster indicates an (admittedly uncertain) spectral type of K3 III. The distance of this star would then be 10.7 kpc (R≈19 kpc), consistent with the kinematic distance and confirming that this is truly a star cluster at the very edge of the Galaxy.

More details can be found in Brand & Wouterloot 2007, *A&A*, 464, 909.

The Abundance Profile of CO in Neptune's Atmosphere

Brigette Hesman (*NRAO*), Gary Davis (*JAC*), Henry Matthews (*NRC/HIA*), & Glenn Orton (*NASA JPL*)

Using the JCMT and the CSO, carbon monoxide (CO) was discovered in the stratosphere of Neptune through the detection of the *J*=3–2 and 2–1 rotational transitions in emission at 345.8 and 230.5 GHz respectively (Marten *et al.* 1993). This discovery was unexpected because CO is not thermochemically stable at observable levels; it was conventionally thought that Neptune's atmospheric carbon must be in its reduced form of methane (CH_4).

Two explanations have been proposed for the presence of CO in Neptune's stratosphere. The first consists of CO being transported from the interior to higher altitudes by convection due to Neptune's strong internal heat source. If this were the only mechanism, then thermochemical models require the interior to be enriched in oxygen by 440 times over the solar abundance in order to produce the observed stratospheric CO abundance (Lodders & Fegley 1994), and indicate a planetary interior composed primarily of water ice. The second hypothesis involves the external supply of OH radicals or oxygen atoms into the atmosphere where they can be combined with by-products of methane photochemistry to produce CO (Rosenqvist *et al.* 1992). It is unlikely however that an external supply of oxygen can be the dominant source of CO in Neptune, considering that Saturn has more abundant water sources (rings, satellites) but a much smaller stratospheric CO abundance ($<10^{-7}$ compared to 10^{-6}) (Noll *et al.* 1986).

In order to determine the correct mechanism, a measurement of the CO abundance profile through the atmosphere is required. This is best accomplished by high spectral resolution measurements that cover a large bandwidth so that a single observational technique can resolve the narrow emission core and the broad absorption line that result from the stratosphere and troposphere respectively. The heterodyne receiver B3 at the JCMT was used to perform this technique; the results of these observations are reported here.

Observations of the CO *J*=3–2 transition in Neptune were carried out on

(Neptune, continued on page 11)

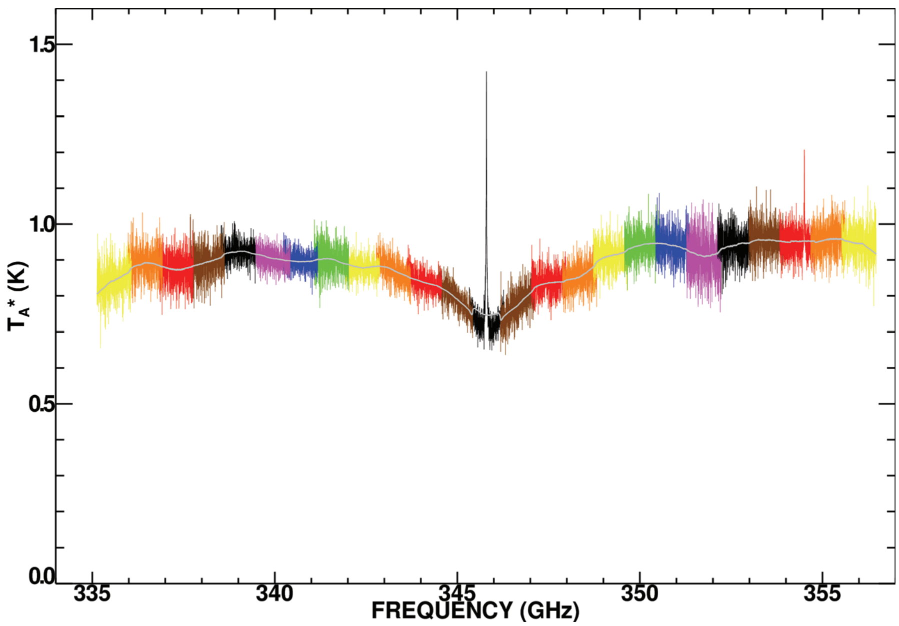

Figure 1. — The antenna temperature spectra of Neptune, measured using receiver B3 at the JCMT. Resolution, 1.25 MHz; band overlap, 70 MHz; bandwidth, 920 MHz. Each of the 25 tunings is indicated by a different color. The grey curve shows a smoothed version of the data.

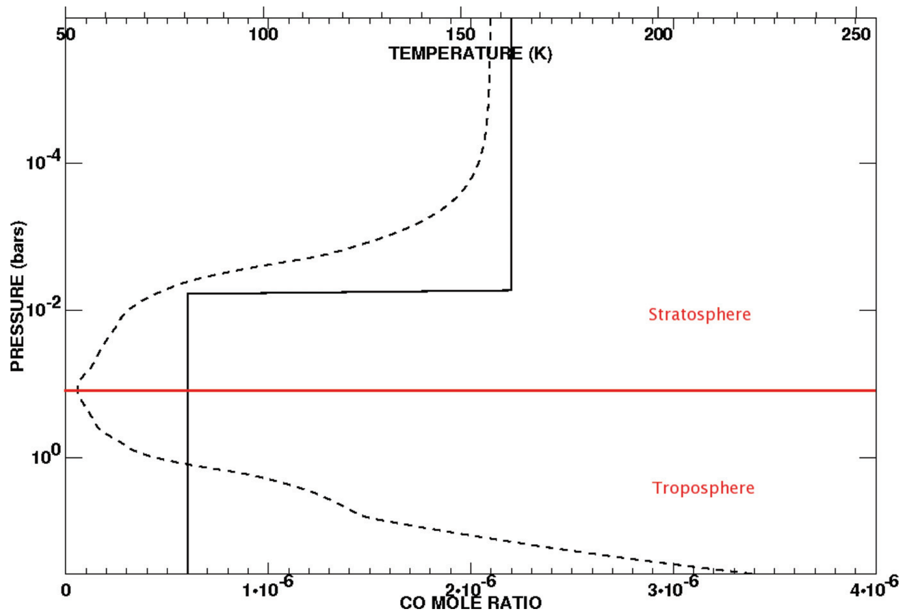

Figure 2. — The model temperature profile (dashed curve) and the CO profile (black) required to produce the best-fit model to the data in Figure 1. The red line indicates the division between the stratosphere and troposphere regions.

Starlink Software Collection: Humu Release

Brad Cavanagh (*JAC Software Group*)

Since the last *Newsletter*, the Joint Astronomy Centre has made another release of the Starlink Software Collection. Named "humu" (Hawaiian for Altair), this release includes major improvements to 3-D visualization. GAIA can now volume render cubes, as shown in Figure 1. This figure shows an iso-surface rendering of a CO map of M 51 (courtesy Remo Tilanus). There are myriad other improvements to GAIA, including being able to examine two cubes and slices through those cubes simultaneously, overlaying more than one cube in the 3-D visualization window for comparison purposes, and more command-line options for better programmatic control.

The humu release also includes a new KAPPA application called PLUCK, which can be used to extract data from interpolated WCS co-ordinates that may not correspond to a pixel centre. For example, with PLUCK you are able to extract a spectrum from any given equatorial co-ordinates from a spectral cube.

Automated file provenance tracking allows one to track input files through the entire history of any file processed with the Starlink software. New KAPPA applications PROVADD and PROVSHOW allow you to add to and view provenance history, respectively.

The humu release includes many more improvements and bug fixes. As always, information about the Starlink Software Collection can be found at `http://starlink.jach.hawaii.edu/`.

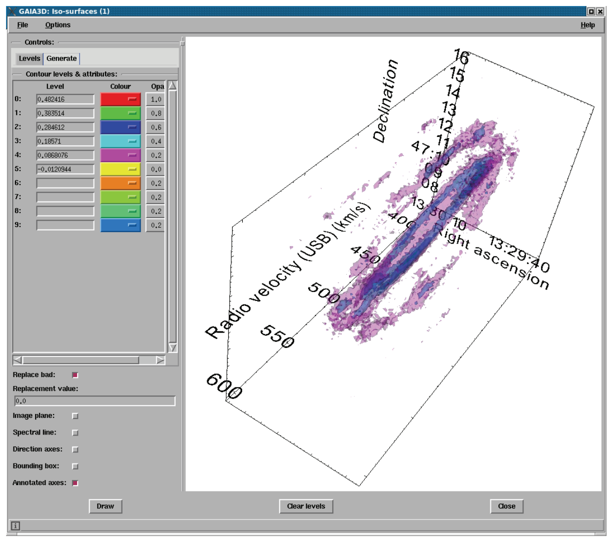

Figure 1. — Gaia 3-D visualization: Iso-surface volume cube rendering of an M 51 CO map. (Image courtesy Remo Tilanus/JAC.)

(Neptune, continued from page 10)

a series of dates in 2003 and 2004. The stratospheric emission core is easily measured due to the high resolution achievable by heterodyne receivers. The tropospheric absorption feature, however, is strongly pressure-broadened and covers a large frequency range (~20 GHz). This makes it significantly more difficult to measure with traditional heterodyne techniques. The line was therefore measured in 25 discrete segments with tunings spaced by 850 MHz, a resolution of 1.25 MHz, and a frequency overlap at each tuning of approximately 8%. The overlap between tunings was necessary to provide an indication of baseline continuity.

The measured CO feature is shown in Figure 1, with the tuning bands indicated by different colors. Baseline continuity was crucial in order to avoid post-processing baseline adjustments which would severely limit the accuracy of the data set. Fortunately, the instrument calibration stability was such that the data quality was excellent and no such adjustments were required. The observations ultimately covered a frequency range of approximately 20 GHz around the central frequency of the line.

A Neptune atmospheric model, developed for this project, was fit to the measured spectrum to determine Neptune's CO profile. A best-fit CO profile was determined through a least-squares fit in which the tropospheric abundance, stratospheric abundance, and pressure level of the transition layer were independently adjusted. The best-fit abundances are 0.6×10^{-6} in the troposphere and lower stratosphere, increasing with altitude to 2.2×10^{-6} in the upper stratosphere (Figure 2).

The measured CO abundance profile indicates the presence of both an internal source, which provides the tropospheric and lower stratospheric CO, and an external source which provides additional CO to the upper atmosphere. It is postulated that the external source could be due to a cometary impactor in Neptune's past since meteorites and planetary grains cannot completely account for the additional CO in the upper atmosphere.

For further details, see Hessman *et al.* (2007).

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Lodders, K. & Fegley, B. 1994, *Icarus*, 112, 368.
Marten, A., *et al.* 1993, *ApJ*, 406, 285.
Noll, K. S. *et al.* 1986, *ApJ*, 309, L91.
Rosenqvist, J. *et al.* 2002, *ApJ*, 392, L99.

Pointing the Way: The JCMT Pointing Project

Iain Coulson (*JCMT Support Scientist*)

Introduction

JCMT has produced superb submillimetre astronomy over the past twenty years, some of which is highlighted in this and earlier issues of the *JCMT Newsletter*. It has revolutionized our view of the Universe near and far with detections of distant, dusty galaxies, images of nearby, dusty, debris disks, and spectra of galaxies, clouds, stars and various solar system bodies taken at molecular transitions too numerous to mention. On their own, and presented without regard to strict precision, such data might still have the ability to amaze. But making scientific sense of such data, often by comparison with other data taken at other telescopes, requires, at a minimum, that it be known from where the data come. What position on the sky, or what part of the object in question was observed? If you can't assign a specific location to your data they may be as good as useless! It's the business of the Pointing Project at JCMT to ensure that such assignments are as accurate as possible.

In the era of space telescopes we are accustomed to spatial resolutions of sub-arcsecond dimensions, and in that regard JCMT may seem to have relatively poor capabilities. Its resolving ability (its 'beamsize') is limited by its physical dimensions (15 m diameter primary) to about 15 arcsec at 345 GHz (850 μm). And whereas in the optical or infrared there will be stars near each astronomical target to which the science data can be referenced for positional accuracy, the submillimetre sky is poorly populated by bright, point-like objects. We certainly have no chance of auto-guiding on a bright (submm) source in the field. Pointing with JCMT — something that ought to be a routine part of observing — can be frustratingly time-consuming.

However, JCMT is able to point reasonably accurately, by which I mean "with a random error of about a couple of arc-seconds". I shall try, in this short article, to explain some aspects of JCMT pointing that may comfort anyone wondering if they're sitting on a goldmine of exciting JCMT data, or on a big pile of boron monosulfide.

Submillimetre Pointing Sources

The JCMT pointing catalog is in two general parts; sources that emit submillimetre continuum radiation, and those that emit line radiation, principally the J=2–1 and J=3–2 transitions of CO. The former category comprises mainly blazars, the latter mainly stars of various types; some compact Galactic H II-regions or dark clouds fall into both categories. Objects of all types qualify for our catalog on the basis of their brightness and compactness. In the days of SCUBA a minimum of ~1 Jy was needed to permit continuum pointing to take less than a few minutes of precious observing time, while for our suite of heterodyne spectral line detectors, integrated line strengths of a few Kelvin km/s are needed to facilitate equally rapid 'spectral line' pointing. Objects that meet these conditions, however, are astonishingly rare: only about 30 blazars are brighter than 1 Jy at 850 μm, and the number of suitably bright spectral line pointing sources is not much larger. On average that's only one or two of each type in each 10 deg^2 patch of sky! As a result, the catalog also holds some bright sources that are not entirely point-like: they allow rapid pointing, but with consequent potential loss of precision. When observing in some parts of the sky the observer faces uncomfortable compromises.

The Telescope Pointing Model

So why not just point on something point-like and bright — anything point-like and bright! — before performing the intended observation? Why the need to point on something near the target, something local!? The (potential) problem is that systematic pointing errors may prevent the useful transference of pointing corrections derived in one part of the sky to observations made in another. This will be the case if the structural imperfections of the telescope are poorly understood, *i.e.*, if the telescope model is poorly determined.

These imperfections are *ab initio* unknown to the precision necessary. If the telescope rotated symmetrically about a perfectly vertical axis, on a smooth, flat surface, and was constructed of totally inflexible struts, then its direction of pointing could be simply(!) read from some fiducial marks, or, in practice, from encoders. But, in reality, such is not the case. The antenna rolls on a lumpy, bumpy track, its main (azimuth) axis is not vertical, and its elevation axis is not perpendicular to the azimuth axis — to list only the principal defects. The imperfections are small by engineering standards (the azimuth axis deviates from the vertical by only about 15 arcsec), but they are big enough to have dire consequences for a telescope with a beam of just that size. The track model and the 7-parameter (telescope) pointing model attempt to quantify these imperfections so that the encoder readings can be suitably corrected to yield the direction of pointing.

The three-parameter track model is measured using tiltmeters at three locations on the antenna, and is implemented as a lookup table of corrections. The telescope model is derived from all-sky pointing observations of sources around the sky and the optimization of a fit to those observations implemented as a software package called TPOINT. The

(Pointing, continued on page 13)

(Pointing, continued from page 12)

TPOINT model comprises geometrical expressions of the effect of each known structural defect upon pointing in both azimuth and elevation; the unknown quantity being the amplitudes (coefficients) of those effects in each case. After the pointing data are fit, and the model coefficients derived, the resulting rms scatters of the corrected data reflect the accuracy of the model. The nominal performance of JCMT is characterized by rms scatters on the sky in (azimuth, elevation) of (1.5 arcsec, 1.5 arcsec).

The multi-parameter nature of the model (and the underlying structural knowledge) allows for any systematic trend in the distribution of errors to be identified with a particular defect, and then corrected appropriately. (TPOINT also allows for the correction of other (empirical, unphysical) trends, should there seem to be any). The residuals thereafter should then be normally distributed. If this were not the case, pointing in one direction and observing in another — the scenario that started this section — would impose systematic pointing errors on the science observation. Cautious observers will wish to minimize any and all such potential systematic effects and will "point-up" as locally as possible.

Collimations and Other Terms

Since SCUBA was retired in 2005, we have adopted the single-detector 230 GHz Receiver A as our primary pointing instrument, and performance statistics have not changed much from the nominal (SCUBA) figures above. By comparison with RxA, the pointing of the 16-receptor B-band array, HARP, is complicated by its field rotator (the K-mirror) which lies between the tertiary mirror (the receiver cabin) and HARP (at right Nasmyth). The K-mirror has its own misalignments, which are small, but which have proven somewhat elusive to determine. That particular project is in progress, but data so far (Feb 2008) suggest fitted rms scatters of ~2 arcsec in each coordinate should be possible.

The optical paths from each receiver to the sky are not coincident and so each receiver needs a pair of (azimuth,elevation) collimation constants added to the basic (RxA-) pointing model. With some instruments in the Cassegrain cabin (RxA) and others at Nasmyth (HARP and SCUBA-2) it is also possible that other model terms as yet unexplored (*e.g.*, cabin flexure) may be needed for complete modelling of the pointing of all receivers, although there is no evidence (no unpredictable systematic trends) for such terms at this time.

Pointing in the elevation direction is also found to be a function of the temperature of the antenna; specifically the temperature difference between the front and back legs. When the front legs are warmer than the back legs, as happens when the carousel doors are open during the day, the front legs expand differentially, and the antenna may be imagined to rock back onto its back wheels. The dish is then pointed too high in the sky. The amount of the error has been both estimated (FEA) and observed at ~6 arcsec/deg C.

The Future

We have measured the structural misalignments, the track profile, and thermal characteristics — many, many times! Algorithms in the telescope control software make corrections for track irregularities, antenna temperature, receiver collimations and so on — and these work fine — but we cannot rest on these laurels. While the foundations of JCMT are subject to (slow) subsidence — thus prompting routine inclinometry (track profile measurements) every couple of weeks, and load adjustments on the central bearing every semester or so — earthquakes pose particularly urgent challenges to the maintenance of pointing accuracy. Dedicated pointing runs (redeterminations of the pointing model) have not been warranted for many months, but vigilance is required if new or changing systematics are to be detected early.

All of us at JCMT eagerly await the arrival of SCUBA-2. From a pointing perspective, it should open up new avenues in improving the pointing performance of the telescope since its superior sensitivity will allow detection of many of the fainter blazars currently populating the catalog, and which have, to date, never been used. All-sky pointing may actually live up to its name! With instrument-to-instrument collimations determined on the brighter targets we should be able to transfer what we hope will be the superior quality pointing accuracy of SCUBA-2 to all our detectors.

The (1.5 arcsec, 1.5 arcsec) rms barrier is just waiting to be broken.

Further details of the activities summarized here may be found at the JCMT pointing homepage (http://www.jach.hawaii.edu/JCMT/telescope/pointing/).

Data Processing Developments

The JCMT continues to improve and augment its data processing capabilities. A web log of reduction pipeline and archive product activity and progress can be found at http://pipelinesandarchives.blogspot.com/ .

Au Revoir

Jonathan Kemp
(*Editor, JCMT/UKIRT Telescope System Specialist*)

After more than a decade at the Joint Astronomy Centre, as the editor of and main force behind the *JCMT Newsletter* for the past eight years, and as my collaborator on the most recent editions of the *JCMT Newsletter* these past few years, Gerald will be leaving JAC this summer to take up a position with NRC at HIA in Victoria. Gerald's tireless *Newsletter* leadership, dedication, and contributions will certainly be missed. But we'll always keep a few column inches warm for you. Aloha!

The Night Shift

Jim Hoge (*JCMT Telescope System Specialist*)

Each newsletter, a Telescope Systems Specialist (TSS) is bullied into writing a short article concerning JCMT Operations. After ducking this responsibility for years, I have been caught. I spent many of my formative years in the "Silent Service" and find that I am better at keeping secrets than I am at telling tales. Please forgive my lack of eloquence and simply accept this article as a brief testament to some of those who are really responsible for the successful operation of the world's best (my opinion but shared by many) submillimetre telescope.

I have been a TSS for JCMT nearly eight years. During that time we have retired two receivers (three if you count the "C" band of RxW) and three backend processors. We have added two new receivers, commissioned a much more capable backend processor, completely revised all telescope control system software, installed a new network, added interfaces and controls that allow us to become part of a larger interferometry array, added thousands of square feet of equipment spaces, hosted at least six visiting receivers, upgraded our engineering consoles and secondary mirror electronics, modified our support equipment, rebuilt/reinforced the telescope and carousel for SCUBA-2, and in general have done whatever necessary to ensure that JCMT remains a world class facility. Having said all that, I can honestly say that my own part in all this change was insignificant. *[Editors' note: NOT!]* TSS are trained to operate and do limited journey repairs. The scope of the work accomplished far exceeds my limited talents. That is why I would like to spend a few moments talking about one of the groups responsible for the miraculous transformation and which continues to improve our facility: ETS or Engineering and Technical Services Group.

All observers are familiar with the excellent job done by our support scientists and TSS but most do not see the work done behind the scenes to ensure their Mauna Kea experience is a satisfactory one. Visiting observers are exposed to most of the JAC organization. They talk to Admin regarding hotel and Hale Pohaku reservations. They interact with the Friend of Project while developing their observing plan (MSBs). Observers are briefed and supported by one of our support scientists. Others within the JAC organization are also involved but perhaps indirectly. Without our contingent of software and network engineers, the telescope will not run at all. This group works in the background but observers are indirectly exposed to them every time we have computer or network issues while observing. All of these people are incredibly important and critical to accomplishing your mission.

The Visiting Observer's exposure to ETS is much different; before our heavy engineering SCUBA-2 facilities upgrade period which started in February 2006, our observing night was 16 hours on the sky and visiting scientists would at least see and meet some of our ETS personnel at the beginning or end of shift. Since reopening the facility in September 2006 we have been doing 12 hr shifts and the people that keep JCMT operating are seldom seen. This dedicated (and surprisingly small) group goes to work when the observers and TSS are going to sleep. If this were a VERIZON commercial, I would be talking about the "network". This is the group that keeps our ship afloat.

Observer Interactions with ETS

Getting there: Our ETS group performs vehicle maintenance on our sedans, changes out tires, ensures the brakes work and that the transmission will keep you moving. In short, without ETS you would have to rent a vehicle or take a cab just to get to H.P.

Traveling from H.P. to the summit, things become even more interesting. Now you have to worry about road quality, studded tires, vehicles that are capable of negotiating the dirt roads and unfriendly environment above 3,000 m. ETS maintains our 4 wheel drive trucks. Along with brakes, transmission, fluids, etc., they ensure that snow chains, emergency equipment, satellite phones, and other equipment are available and in good condition.

Snow crew: When you arrive at JCMT, you might not even be able to get into the building without ETS. Snow can fall on Mauna Kea from October through June. Conditions can get bad at any time of the year. We have a snow clearing crew that is on call and will respond rapidly to bad weather conditions. Clearing JCMT is not an easy task with its large flat roof, huge doors and frame structure. In severe weather it can take days to return the facility to full service (think about working in sub zero temperatures at 4000+ m elevation with high wind, intense sun, etc.). When winter hits Mauna Kea, without ETS, you are limited to watching movies and playing pool at H.P.

Inside the building: The JCMT Facility, although not as complex as a nuclear submarine, has an impressive array of advanced (complex) systems including telescope and carousel drive systems, roof and door electronics and pneumatics, cryogenic compressors, chillers, air compressors, electrical distribution systems, the star lift, overhead cranes, etc. ETS works on every system.

Looking up: After the roof and doors are opened and the telescope

(The Night Shift, continued on page 15)

(The Night Shift, continued from page 14)

has slewed to a source, you want to use HARP (or RxA3i or RxW or SCUBA-2). ETS maintains our receivers as well as our back ends (ACSIS). These are complex, unique (one-of-a-kind) pieces of equipment operating in the most unfriendly of places and operating at temperatures where even our normal understanding of physics and electronics is challenged. Think Josephson effect, indium seals and bolometric arrays. Consider the skilled people required to make these instruments work. Although we receive technical support for our newest equipment, the support personnel are thousands of kilometers away and our own ETS group does the actual work.

Operational Support: This same group provides 24 hour support to us while we are operating. Our ETS personnel are so knowledgeable that they can lead a TSS to the correct action over the telephone in many instances. In nearly eight years of operation, I do not remember a single instance in which ETS was unable to bring the facility back to life after a casualty. Most times the problems were corrected between the end of one night shift and the beginning of the next.

As an example, a full year before ACSIS (our new spectral back end) was received, our old backend (DAS) was nearly destroyed by a winter ice and rain storm. Water got into the facility and pooled on the roof of the control room. This water then traveled along conduit and wire trays into the DAS where high speed fans, used to cool the electronics, blew the water all over much of the sensitive electronics. After initial damage control to stop the water from getting into the DAS, our electronics technicians almost completely disassembled this complex piece of equipment. Circuit boards were dripping water, and corrosion started as soon as the water came in contact with these boards. For a full year, ETS had to continually clean and combat corrosion within the system. They kept the DAS operating until it could be replaced. Without the DAS we would have had no spectral capability.

Another example, while observing on New Years Eve, our secondary mirror stopped operating. We were unable to adjust the z axis rendering the telescope unusable. At 8:00 am New Years day, I contacted ETS. By 11:00 am two of our technicians were at JCMT working on the problem. By 5:30pm, the SMU was repaired and we had an excellent night of Grade 1 observing.

The future: ETS does much more than just maintain the facility and all of its equipment. When the cost associated with SCUBA-2 appeared to be prohibitive, ETS agreed to do facility modifications and upgrades along with their normal jobs, to try and save the JAC money that could be used for development. Our machinists and welders made the massive modifications required to support and install SCUBA-2 and ACSIS. Without their support, there probably wouldn't be a SCUBA-2.

In short, ETS deserves a lot more than one page. I had the great pleasure of working with ETS during our infrastructure upgrade and I consider them to be the heart and soul of our facility. Keep in mind, this group maintains both UKIRT and JCMT.

One final note, working at JCMT has been exciting and fun. With the arrival of SCUBA-2 our lives will become even more interesting and I see nothing but good things in the future of JCMT. If management only asks me to write an article every 5 years (or so) then I have only two or three more articles to go before SCUBA-2 and I both retire. I suspect I can manage that.

The Last Word

Gerald Schieven (*Editor, JCMT Support Scientist*)

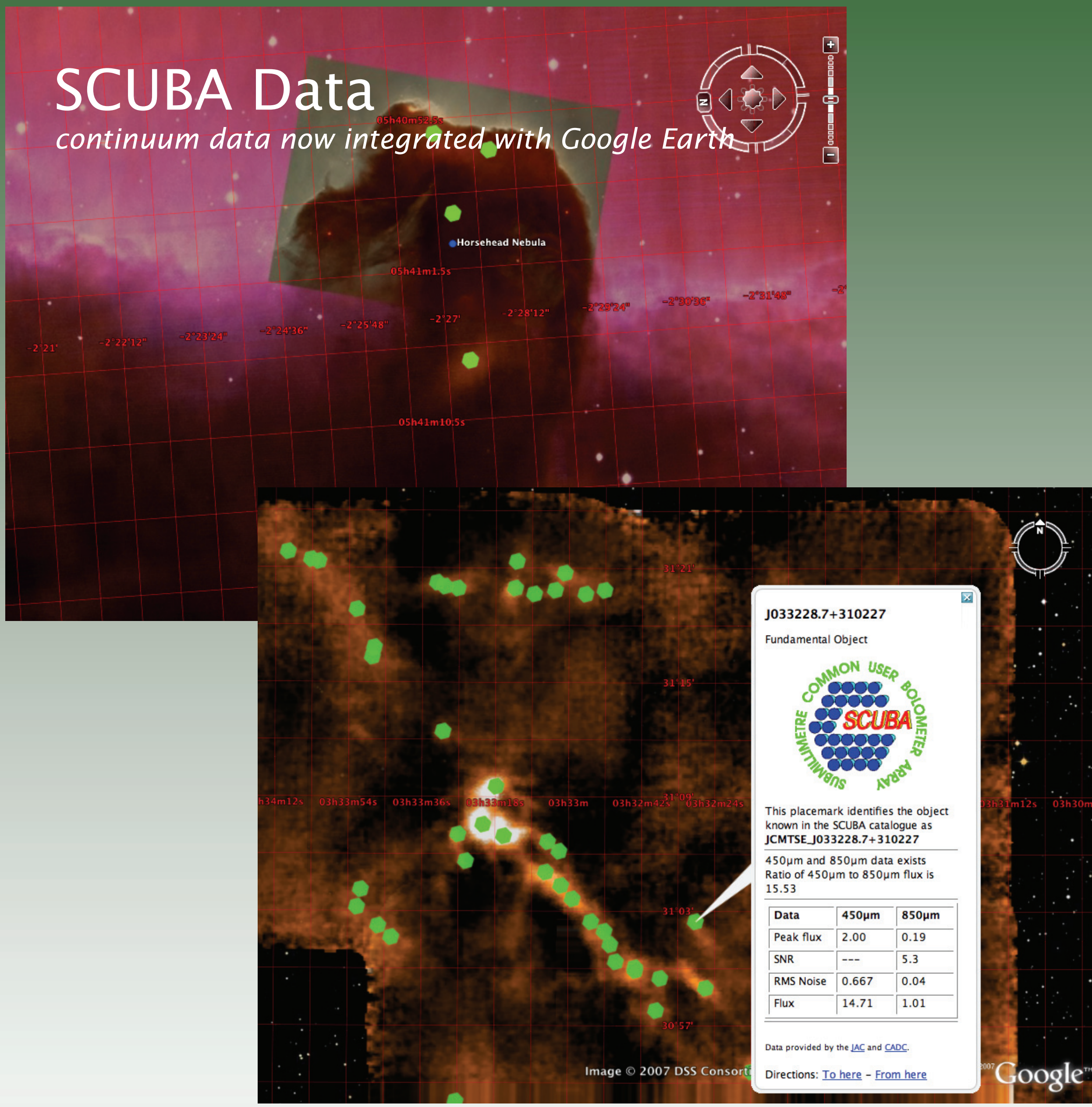
This issue marks my final effort at (co-)editing this *Newsletter*, as I will be leaving in July after nearly 13 years at the JAC. These years have seen *many* major changes here at the JCMT. When I arrived, the only continuum instrument was (the already-venerable) UKT14, our B-band receiver was still single-pixel, single polarization, and double sideband, and higher frequencies were observed with RxG. There was no Observation Management Project (OMP). SCUBA was delivered about a year later, and the following year began operations just in time to make phenomenal use of an extremely dry El Niño over the winter of 1997-98, with week after week of grade 1 weather. More than any other, that instrument *made* the JCMT, and quite literally revolutionized astronomy with its discoveries. It was indeed a heady and exciting time. That heady atmosphere promises to repeat itself now that SCUBA-2 has been delivered.

This issue also marks my 12th as editor/co-editor, and the third which is to be printed glossy-magazine-style. If you're wondering why you've not seen any of the previous issues lying on coffee tables, we've unfortunately had some "issues" with the printer. The first printing came back with some glaring problems, which took much time sorting out. The second issue was put out for bid after sorting out the first issue, and should be delivered to us soon. Both issues will then be sent out together. Now that we have a printing company, the current issue should be ready to mail out much more quickly (we hope!).

Editing the *Newsletter* has been one of the highlights of my tenure here at the JAC, and working with Jonathan Kemp (my co-editor for the past four issues) has been very rewarding. I'm not sure who will be co-editing with Jonathan, but if you have an idea for an article for the *next* (fall 2008) *Newsletter*, please send it to him at j.kemp@jach.hawaii.edu.

SCUBA Data

continuum data now integrated with Google Earth



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