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# *The JCMT Newsletter*

Kulia I Ka Nu'U

The JCMT Newsletter

Number 17

September 2001

Fred Baas, 1944-2001

**September 2001 Issue Number 17**

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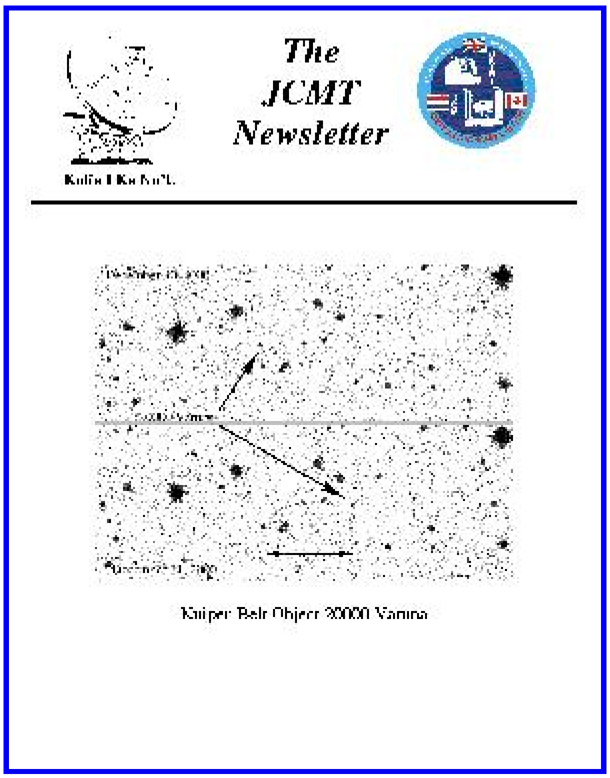


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*Gerald Moriarty-Schieven*

# From the Director's Desk

The last six months were overshadowed by the tragic death of Fred Baas. Fred was one of the kindest and nicest people that anyone could meet and he was very well liked. His sudden and untimely death left the JAC with a deep sadness. Indeed, it is hard to believe that he's gone from us.

Now turning to operations, unfortunately the optimism I expressed in the last Newsletter regarding the excellent weather was short lived. Since then the weather has been quite dreadful, with only the occasional brief spell of decent observing conditions. The major event of the period was the JCMT Board meeting in May, where the Board (and agencies) supported SCUBA-2 being funded by the JCMT Development Fund until November pending decisions from the UK Office of Science and Technology regarding funding (since approved). Wayne Holland provides an update on the exciting SCUBA-2 project later in this Newsletter. The Board will need to revisit the SCUBA-2 project in November.

The Board also agreed that to save on staff effort, an experiment would be undertaken whereby the Annual Report would be published only on the Web and would be a condensed version of the previous glossy publication. Much of the key user information (such as project status) will, in future, be confined to the Newsletter, which is much more timely. The Annual Report will primarily serve as an audit of the top-level activities of the JCMT. In this vein, it was also brilliant to find that in the calendar year 2000, the JCMT refereed publications reached 100, dominated by SCUBA. Furthermore, in citations to high impact papers in 1999, SCUBA was second only to the HST, beating all other facilities and satellites. This is a brilliant achievement and SCUBA continues to provide truly exciting new scientific discoveries as shown by the breadth and depth of the science articles in this Newsletter.

JCMT operations continue to be very tightly pressed. However, the new Telescope Support Specialist rotation of 4+12 hours seems to be working well in achieving our 16-hour operation, albeit with the unavailability of extended hours after second shift in good conditions. HARP-B is making good progress, and although there have been problems with the supply of SIS devices, very recently this seems to have improved. Unfortunately, ACSIS has run into a number of problems following the CDR last December and progress on fabrication of the downconverter modules has proven to be a major stumbling block. While the Board approved the principle of the increased funding required to complete the spectrometer, a final report on the satisfactory route forward is still awaited before this can be released. It is clear that ACSIS is going to be delayed, but to what extent is not yet clear.

As a result of a PPARC request, a significant amount of management effort has gone into identifying possible operating models for the JAC post 2006, a time when the JCMT (and UKIRT) is expected to be operating primarily in a wide-field mapping mode. This will be debated during the autumn with decisions in principle expected by the end of the year.

I was particularly pleased when I heard that PPARC had awarded part-funding for an outreach specialist post at the JAC. From a very high quality field of applicants, Douglas Pierce-Price from MRAO was appointed. He will join us later in the autumn and as part of his work he will also be making a notable contribution to SCUBA image processing software that will be of major benefit to users, especially those for wide-field mapping projects.

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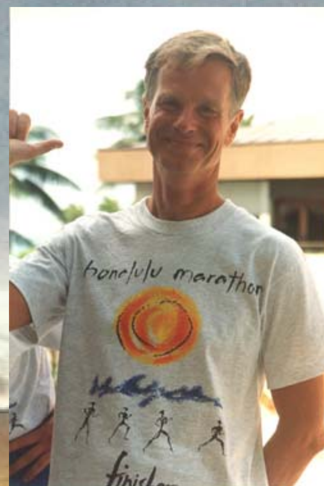
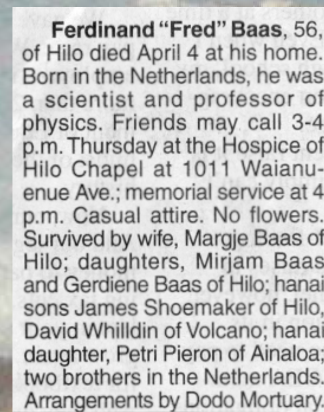
*Ian Robson - Director JCMT*

# Fred Baas, 1944-2001

April 3, evening



**Ferdinand "Fred" Baas**, 56, of Hilo died April 4 at his home. Born in the Netherlands, he was a scientist and professor of physics. Friends may call 3-4 p.m. Thursday at the Hospice of Hilo Chapel at 1011 Waianuenue Ave.; memorial service at 4 p.m. Casual attire. No flowers. Survived by wife, Margje Baas of Hilo; daughters, Mirjam Baas and Gerdiene Baas of Hilo; hanai sons James Shoemaker of Hilo, David Whilldin of Volcano; hanai daughter, Petri Pieron of Ainaloa; two brothers in the Netherlands. Arrangements by Dodo Mortuary.

Obituary

(April 4)

Dear friends and colleagues of Fred and Margje,

It is with great sadness that I have to let you know that Fred peacefully passed away this morning while at home and surrounded by his family. Yesterday evening he still enjoyed a small 'party' at his home (see picture) with a beautiful Hawaiian sunset and a rare clear view of Mauna Kea from his back porch. But after the night he knew it was time to let go and slipped away quietly. He went the way he wanted to go, like he did everything else in his life.

Margje and the kids are at peace with it and glad that he did not have to suffer any longer. For those who sent them emails with greetings and encouragements: Fred read them all and Margje told me he appreciated and enjoyed the messages. Your support, even from afar, has been and continues to be a great comfort to them.

sincerely, Remo Tilanus

## JAC Announcement

It is with deep regret that we have to announce the death of Dr Fred Baas on Wednesday April 4th 2001.

Fred had been a support astronomer at the JCMT since 1989, and had given loyal and high quality support to countless users over the years. He enthusiastically served the JCMT and local Hilo community for many years. Many of you will have been helped and supported by Fred and will join with his astronomy colleagues in the Netherlands and us in mourning his loss.

For many years at the JAC, Fred continued his research with colleagues in the Netherlands, but over the past few years his focus turned to the challenge of understanding the deformations of the JCMT surface. The knowledge gained by Fred led directly to the important surface upgrades project.

As well as his work for the JCMT, Fred was an enthusiastic teacher at the University of Hawaii in Hilo. He loved the teaching and was extremely popular with students. Fred was also completely at home with the outdoors life and became an ardent runner and cyclist. He had a long held ambition to participate in the Hawaii Ironman Triathlon. Happily he not only qualified but also completed the challenging race last October. However, it was shortly afterwards, in December last year, that Fred was diagnosed with a malignant melanoma. Despite intensive treatments in Honolulu, Fred lost his battle with the cancer and passed away on Wednesday morning (April 4th). He was at home with family and left this world with dignity.

Fred was a loving family man and leaves behind his wife Margje and two daughters Mirjam and Gerdiene. Our sympathies are with them. Colleagues wishing to make donations in lieu of flowers should send these directly to Fred's family, c/o the Joint Astronomy Centre, 660 N.Aohoku Place, Hilo, Hawaii 96720, USA.

Original homepage Baas

## JCMT shutdown in the summer of 2002

**Plans are firming up for a service shutdown of the JCMT in the summer of 2002. Why are we having a service shutdown? One issue to be addressed by the shutdown is the problem of the sticking filter drum on SCUBA. This problem started in December 1999, making it impossible to use any other filter than the 850/450-wideband combination. Repairing the filter drum will take SCUBA out of action for several weeks and is not risk free. ITAC has weighed the scientific motivation for a repair against the outage and risk. It was decided, at the June 2001 ITAC meeting, to do the repair during the summer 2002. During the shutdown, we will also replace the bad indium seal. Other SCUBA work under discussion are fridge repair/maintenance, replacing the 850 micron filter with new edge filter, wide-band 850-750 micron filter, new 850 micron array feed horns and fixing broken or noisy pixels.**

**We also need to shut down the telescope in order to do preparation work for the B-band array HARP-B. The array has a K-mirror for image rotation that will be located in the cabin. In order to install the K-mirror the cabin needs to be modified. Further, all helium lines for the closed-cycle coolers in the cabin need to be rerouted. The work will involve electrical welding as well as cutting metal burs. Due to the risk of damaging the SIS junctions and receiver optics, all heterodyne receivers will be removed from the cabin during this work. The antenna will be immobilized during this work stopping all observations allowing for extended working days to complete the task as quickly as possible - making the antenna ready for SCUBA observing each night would be very inefficient if even possible.**

**To minimize the loss of SCUBA observing time we plan to overlap the shutdowns as much as possible. We have insufficient staff to do all work in parallel. Other factors affecting the planing is availability of ATC staff needed for the SCUBA work and avoiding other labor intensive work at the JAC such as the move of Michelle to Gemini. The current plan, which not is final, is outlined below.**

**June 13th SCUBA work starting with warmup.**

**June 24th Heavy engineering starts, heterodyne receivers removed and antenna is closed.**

**July 15th SCUBA work finished and cool-down starts.**

**July 22nd Heterodyne receivers returned to cabin, pumping and preparation for cool-down starts.**

**July 23rd SCUBA observing starts - still extended day work.**

**July 26th Extended day work ends - 16 hours observing starts.**

**Aug 2nd All instruments in operation.**

**The final schedule will depend on the amount of SCUBA work attempted as well as need for contingency time.**

**Per Friberg**

**2001/08/30**

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# *JCMT/SCUBA Citations in 1999/2000*

~~JCMT publica tion history~~

The years 1999 and 2000 were banner years for JCMT publications, in particular for SCUBA. The number of refereed, JCMT-related publications in 2000 reached 100 for the first time in our history. Furthermore in a 2001 paper by Benn and Sanchez (2001, PASP, 113, 385) on the scientific impact of large telescopes, citations from JCMT data during the 1995-1998 period accounted for 1.3% of all astronomy citations (c.f. IRAM 0.8%) (the total for all of submm and radio astronomy was 4%).

As further evidence of the profound impact that SCUBA and the JCMT are having on the field of astronomy, at the STIC meeting on 15 June 2001, George Meylan (STScI) presented a compilation of the number of citations to high impact papers published in 1999, based on instrument/facility. Citations to papers are only counted if the paper has received at least 50 citations, ensuring that only high-impact papers are counted.

As can be seen below, SCUBA came second only to the HST (by a significan margin) in terms of impact - clearly the most important ground-based instrument in recent memory. Furthermore, two of the top-ten cited papers in 1999 were SCUBA papers.

# Citations to High Impact Papers, published in 1999

Compiled by Georges Meylan, STScI, Baltimore, as presented to STIC on June 15, 2001

| | |
|---|---|
| HST | 415 |
| SCUBA | 368 |
| ROSAT | 205 |
| CGRO | 196 |
| Keck | 180 |
| BeppoSax | 180 |
| Soho | 121 |
| CTIO4 | 110 |
| WHT | 84 |
| RXTE | 83 |
| Hipparcos | 72 |
| ASCA | 68 |
| Pal200 | 65 |
| KPNO4 | 52 |

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*Gerald Moriarty-Schieven*

# The Nightwatchman

Edition 2

Autumn 2001

Hilo, September 1

## TSS Support

Since our last newsletter, the JCMT TSS corps has entered a relatively stable period. The 16-hour operational model, with complete support for the twin eight-hour shifts and minimal support for extended observing, has continued with moderate success. Since the spring, we have been able to support nighttime observing completely. This arrangement is expected to become more permanent in the fall as an agreement on how to appropriately formally and fully implement the 16-hour model seems imminent.

In addition to Robin Phillips and Nick Jessop occasionally supporting nighttime operations at the telescope, recently hired support scientist Jan Wouterloot has begun training and will shortly start a similar program of augmenting his daytime duties by aiding in the nighttime operation of JCMT.

## Weather

Robin Phillips has been working on the software implementation for collecting data with the 186 GHz Water Vapor Monitor located in the JCMT receiver cabin. This data is collected every 6 seconds along the line-of-sight of the JCMT antenna and is operational whenever the dome is open. The results are transformed to tau_(225 GHz). More information on this instrument is available within this edition of the JCMT newsletter. The real-time data can be found at www.jach.hawaii.edu/~jkemp/wvm.

Meanwhile, with the production of additional, real-time atmospheric water vapor information and in consultation with my colleagues, I have developed a centralized, real-time Mauna Kea weather page that can be found at www.jach.hawaii.edu/~jkemp/wx. Feedback on this page is appreciated.

## Antenna and Instrumentation

Following the discovery of the occasional 50 MHz shift in the Gunn oscillator output frequency of receiver B, which causes a 200 MHz offset in receiver tunings, a camera has been placed in the receiver cabin to send the display of this Gunn oscillator output frequency to the control room so that the problem can be immediately diagnosed and the loss of observing time avoided.

The installation of a new climate control system in the computer room at JCMT has appeared to stabilize the environment in which the DAS functions and has curtailed what were surmised to be temperature-dependent failures of the DAS that have plagued heterodyne observing for the past several weeks.

## Notes for Observers

We would like to remind observers to include detailed information about cells and switching in their heterodyne observing templates. For the cell, both the size (in arcseconds) and angle of orientation (north = 0 degrees, east = 90 degrees) should be specified unless the observation is merely of a central position specified by the source coordinates. For switching, each method has its own set of parameters.

Beam switching requires a chopping distance (in arcseconds, up to three arcminutes), a frequency (usually at 1 Hz with the DAS and 7.8125 Hz with the CBE), and an angle (usually in azimuth for various reasons, but possible in any direction). Position switching requires an x,y pair of offsets (in arcseconds). Lastly, frequency switching requires a specified frequency (usually 8.2 MHz, or some multiple thereof). Please note that "grid" mapping and "raster" mapping observing methods each have special considerations when it comes to a choice of switching.

If you are unsure which type of switching you should use for your program, please consult the JCMT User's Guide on the web or the support scientist contact for your program.

La Citation du Semestre

And suddenly, I had a vision of the face of destiny. Old bureaucrat, my comrade, it is not you who are to blame. No one ever helped you to escape. You, like a termite, built your peace by locking up with cement every chink and cranny through which the light might pierce. You rolled yourself up into a ball in your genteel security, in routine, in the stifling conversations of provincial life, raising a modest rampart against the winds and the tides and the stars. You have chosen not to be perturbed by great problems, having trouble enough to forget your own fate as a man. You are not the dweller upon an errant planet, and do not ask yourself questions to which there are no answers. You are a petty bourgeois to Toulouse. Nobody grasped you by the shoulder while there was still time. Now the clay from which you were shaped has hardened, and naught in you will ever awaken the sleeping musician, the poet, the astronomer that possibly inhabited you in the beginning.

Antoine de Saint-Exup?ry, Terre des Hommes, 1939

Happy December eclipse chasing (annular solar and penumbral lunar)!

Jonathan Kemp

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# An update on SCUBA-2: the new wide-field imaging camera for the JCMT

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**Wayne Holland & William Duncan** - *ROE/ATC*

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SCUBA-2 is a new, wide-field submm camera planned to replace SCUBA(-1) on the JCMT in 2005/6. The science goals and baseline design were described in an article in the Sept 2000 newsletter. Considerable progress has been made since then, and this article aims to provide an update on some of the major developments that have taken place in the past year. Although the SCUBA-2 project remains only partly funded, a very valuable contribution of 4M UKP was recently awarded by the UK Office of Science and Technology towards the total project costs (estimated to be 8.9M UKP).

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### 1. Science Drivers and Baseline Design

The science drivers for SCUBA-2 are well-established, but for anyone not familiar with the instrument, and as a way of an introduction, it's worth re-emphasising the main science goals:

- Deep imaging. This is very time consuming with SCUBA - relying on co-adding lots of frames of data over periods of many hours (especially difficult at 450 microns, where it is rare to have extended periods of good, stable weather). SCUBA-2 aims to reach the extragalactic confusion limit at 850 microns in around 1-2 hrs, instead of ~50 hrs at the present time.

- Maximise the survey potential. Even though SCUBA has been a big step forward in terms of mapping large areas of sky, only an area about the size of a full moon has been mapped to any great depth (near the confusion limit). SCUBA-2 aims to map large areas of sky at least several hundred times faster than SCUBA to the same S/N.

- Improve image fidelity and map dynamic range. SCUBA requires a minimum of 128 secs to produce a fully-sampled map at both 450 and 850 microns. In addition, because SCUBA can only record an AC signal (i.e. chopped signal) we are constantly subtracting two images of the sky. SCUBA-2 will aim to improve data quality by instantaneously sampling the sky, and operate in a mode that avoids the necessity to sky chop.

- Imaging at two colours simultaneously. This has been successful with SCUBA - for example, it allows meaningful studies of dust properties, as well as utilizing periods of good weather to exploit the higher angular resolution available at shorter wavelengths. SCUBA-2 aims to continue in this mode.

- Act as a "pathfinder" for submm interferometers. By coming on-line in 2005/06 SCUBA-2 should have at least a few years of observations before ALMA begins full operation. Wide-field surveys will be crucial to fully-exploit the capabilities of the new generation interferometers.

The instrument challenge is therefore to take these science drivers and incorporate new developments in detector technology to design the first "Submm CCD Camera"! To achieve the science goals requires that the instrument have:

- Per-pixel sensitivities to be dominated by the sky background photon noise (fundamental limitation). This requires improvements of a factor of three over the current SCUBA bolometers.

- The maximum (undistorted) field-of-view allowed by the telescope. This turns out to be 64 sq-arcminutes (c.f. to only 4.3 sq-arcmins for SCUBA) - a factor of 16 times larger field.

- Fully-sampled imaged planes and DC-coupled electronics (no sky chopping) to improve image fidelity and map dynamic range. This requires 25,600 and 6,400 pixels at 450 and 850 microns, and ultra stable electronics at low (DC) frequencies.

- A dichroic beamsplitter to split the short-wave and long-wave channels onto two separate arrays. Thus, simultaneous observing will be available with two colours.

## 2. Array Development

### *2.1 Superconducting detector development*

Conventional bolometer technology (such as that used in SCUBA) is not practical for the pixel count required for SCUBA-2. The SCUBA-2 arrays will utilise superconducting Transition Edge Sensors (TES), with the signals read-out using time-division SQUID multiplexers. The array development is being led by the National Institute of Standards and Technology (NIST) in Boulder, and the Scottish Microelectronics Centre (SMC) in Edinburgh. Earlier this year research agreements were signed with both NIST and SMC to produce prototype and science-grade arrays for SCUBA-2. An "Array Technology Meeting" was subsequently held in Boulder which led to the baseline design for a single-pixel and initial concepts for an array structure.

### *2.2 Pixel and array design*

Several crucial decisions were made at the Boulder meeting. Figure 1 shows a schematic drawing of the novel SCUBA-2 pixel design, together with a concept for the array geometry. The design consists of an upper detector chip and a lower multiplexer (MUX) chip, which are held together with indium bump bonds. The detector chip consists of two silicon wafers diffusion bonded together, with the top wafer having micro-machined square wells to provide support for the array. The upper surface of the bottom wafer forms the radiation absorber, and is ion-implanted to give a surface impedance match to free space. The backshort for the absorber is formed by the TES device itself, which covers the entire underside of the pixel, and is a one-quarter wavelength distant from the absorber. This integral backshort design greatly simplifies the construction of the array. Electro-magnetic modeling of the pixel and array geometry shows that the absorption efficiency is likely to be at least 90%.

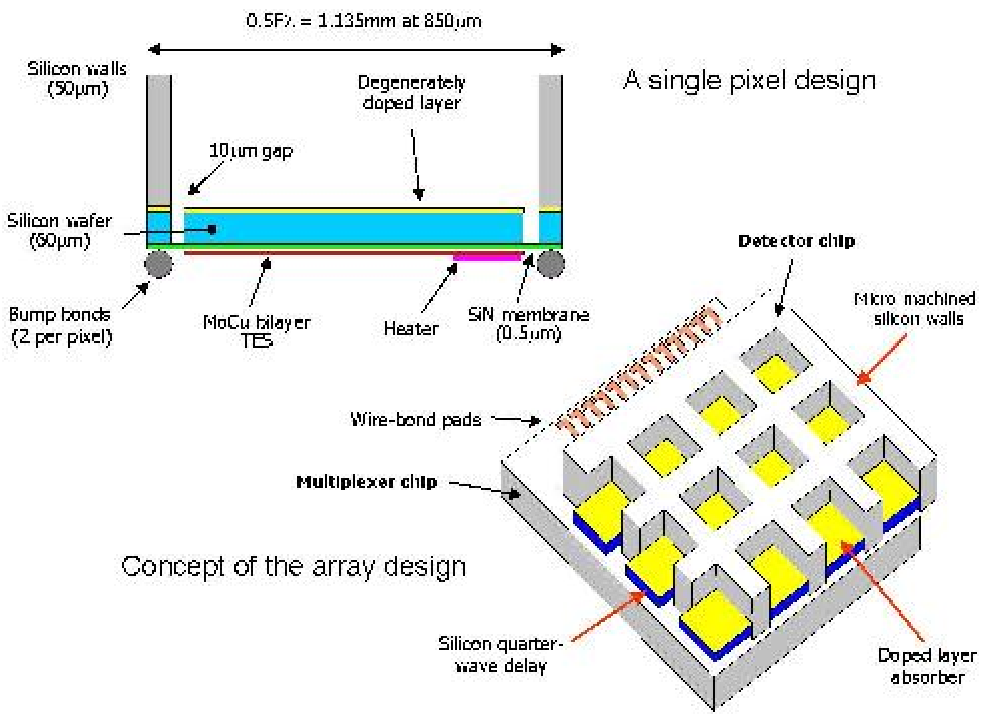


*FIGURE 1: (a) Single pixel schematic diagram (b) Concept of the array architecture design*

*2.3 Multiplexer design*

The hybrid detector design means that each pixel has a SQUID amplifier and coupling transformer directly underneath on the MUX chip. The MUX design is critical in that it has to minimise signal crosstalk due to magnetic coupling between adjacent pixels. The maximum area available for the MUX is therefore limited by the size of the pixel (~1mm and 0.5mm at 850 and 450 microns). At 450 microns there is simply not enough space for all the coupling inductors in the low-crosstalk design. Rather than undergo an extensive re-development programme for a separate 450 micron MUX, it was decided to make the 450 micron pixel size the same as the 850, with the consequence that the 450 array would now have 6400 pixels and be instantaneously undersampled by a factor of 2 (pixels spaced by F-lambda in the focal plane).

Although this sounds like a step backwards, the scientific consequences are not that great. The large-area mapping speed is reduced by a factor of 2, a micro-step pattern will be needed to produce a fully-sampled map (only a 4-point jiggle is needed), and the beam size on the sky for each pixel is about 14% broader. Given the alternatives (a complex and lengthy re-development MUX programme) these losses were considered to be acceptable to minimise further risk in the array development. In fact, there are also some advantages such as the pixels at both wavelengths having the same physical size (making fabrication techniques inherently simpler), and fewer channels of detectors (making the electronics simpler and cheaper).

*2.4 Focal plane layout*

The optical design (see below) and the necessity to have the pixels at least a wavelength in size means that each focal plane will be approximately 90mm in diameter. Silicon micro-machining at the SMC is confined to industry standard 3-inch wafers. Hence, a focal plane layout has been adopted that consists of 4 separate sub-arrays at each wavelength. Each sub-array will have 40 x 40 pixels, and will be butted together as shown in Figure 2.

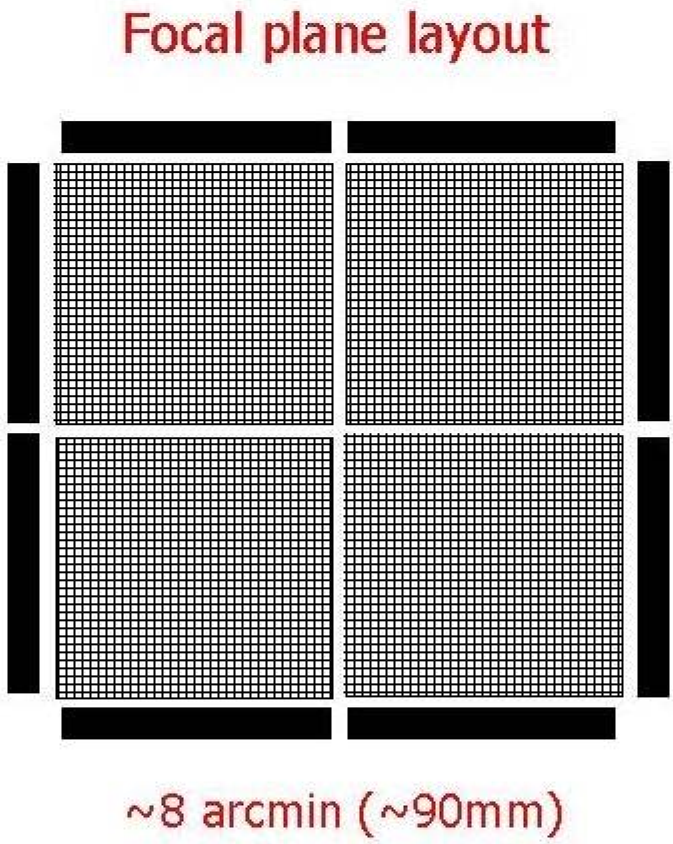


*FIGURE 2: Array focal plane layout showing the 4 sub-arrays butted together.*

*2.5 Progress to date*

Since the Array Technology Meeting in February, work has concentrated on the design and manufacture of single TES pixels and linear multiplexers, as well as developing the techniques needed to construct large-format arrays. The single-pixel design, as mentioned above, is largely complete and NIST are now starting to produce test single-pixels with the desired thermal and electrical properties. Crucially, this means that the pixels must have the correct noise equivalent power and time response to meet the science goals. Some problems with the Mo and Cu guns in the plasma deposition system have prevented the production of test TES pixels until now. These have been resolved and the programme can now re-commence. This will start with the fabrication of some x-ray pixels to show that earlier designs can be reproduced.

The MUX manufacture is already ahead of schedule with a 1 x 32 prototype already undergoing cold dip testing. The initial results, stepping through the addressing very slowly look very encouraging. A 4 K dip probe is being developed to allow testing at the full MUX addressing rates. Testing should commence at the end of September. Figure 3 shows the overall system read-out scheme, highlighting some of the components that will be incorporated.

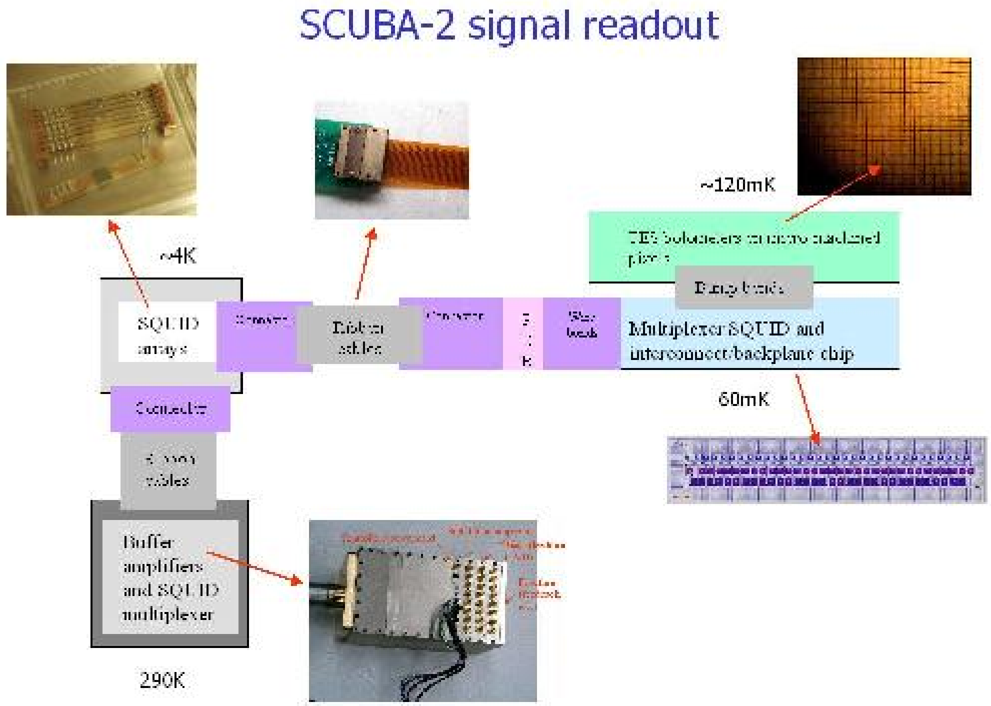


*FIGURE 3: SCUBA-2 signal readout scheme showing photographs of some of the components.*

A considerable amount of work has also been carried out at SMC on developing and testing array manufacture techniques. Implanted wafers have already been made and have demonstrated excellent absorption efficiency in tests at Cardiff University. The SMC is also investigating the best way to manufacture the silicon backshort and sourcing vendors for the bump-bonding process.

## 3. Instrument Design

### *3.1 Optics design*

In parallel with the array development, work is proceeding at a healthy rate on the instrument design at the ATC. The optics design is a crucial part of this, as it has a significant bearing on the size of the focal plane, the size and shape of the cryostat needed, and the location of the instrument on the telescope.

There are complex trade-offs in the design involving minimising the field distortion and maximising the Strehl ratio over an 8 arcminute field, as well as ensuring that the focal plane is a manageable size. Optimisation of the design using Zeemax allows for the final optics to be f/2.7, accommodating individual pixels sizes of ~1mm and a array diameter of some 90mm. However, at the tertiary mirror of the telescope, the re-imaged field is some 600mm in diameter, and so SCUBA-2 requires a complex set of optics using large mirrors with complex shapes to re-image the field onto the detector array with maximum efficiency and minimum distortion.

Another important aspect of the optical design is minimising any stray light from reaching the arrays that can potentially degrade sensitivity. This is particularly important for SCUBA-2 since the detectors have no feedhorns to define their field-of-view (they have an approximate PI steradian f-o-v). In the SCUBA-2 design the field-of-view is controlled by a cold stop some 300mm in front of the array, and it is therefore vital that a high quality pupil image be attainable at this point in the optics. Other complexities involve how the images will "sheer" as the telescope moves in elevation, and flexure issues concerned with how the mirrors are mounted.

Taking all these issues into account, we are currently considering locating SCUBA-2 on the antenna floor - underneath the Nasymth platform, but still attached to the telescope A-frame. An initial concept for this is shown in Figure 4. The main advantages of this are that it becomes much easier to control the quality of the cold-stop pupil image (the current design shows this to be the excellent), puts the instrument in an area that has more space around for electronics, and potentially allows much easier access for future add-on instruments (such as a polarimeter or an FT/grating/F-P spectrometer). Optimisation of this design is currently underway.

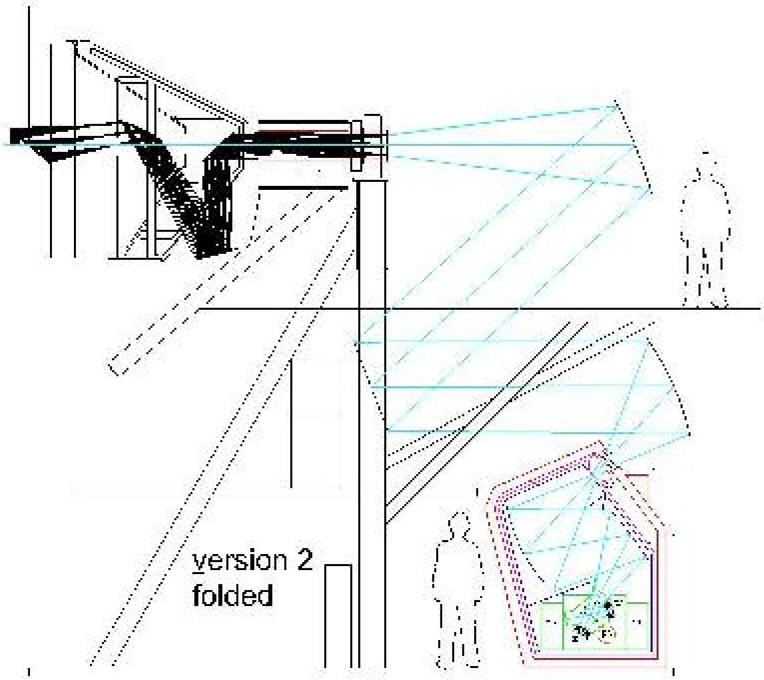


*FIGURE 4: (a) Possible location for SCUBA-2 on the telescope.*

*3.2 Systems analysis: operational modes*

Work is also ongoing in defining just how we will observe with SCUBA-2 on the telescope. Carrying out this work up-front is crucial, as it will likely impact on the opto-mechanical design. The two basic observing modes will be STARE-MAP - it's simplest form being a "point-and-shoot" mode for sources comparable in size or smaller than the field-of-view, and SCAN-MAP - rastering the telescope across an extended source that is larger then the f-o-v. It is likely that each of these basic modes will have several configurations depending on the source morphology and how deep an integration time is required. One of the fundamental differences between SCUBA-2 and SCUBA is how the (dominant) background emission is determined and subtracted. Instead of sky chopping, which increases the confusion limit and limits the visible source-size scales, it will be up to the astronomer to decide just where the sky background is.

An example of how the systems analysis work has an impact on the instrument design is that a cold dark shutter is being designed into the instrument to allow "dark frames" to be taken. The frequency of the dark measurements depends critically on the low-frequency (DC) stability of the detectors and electronics. Other crucial areas include how to deal with variations in detector responsivity (which is very dependent on the sky background) and also how to cope with atmospheric sky-noise. We are currently developing various simulation tools to assist in determining how best to use the instrument, given atmospheric instabilities and variations in detector response. This work is being carried out with the assistance of Rudolf Le Poole (Leiden) and Hans von Someron Greve (ASTRON) and also David Hughes and Ed Chapin (INAOE).

### *3.3 Cryo-mechanical design*

The cryo-mechanical design is challenging! Two 250 x 250mm focal plane structures must be integrated into a cryostat and cooled to ~60mk. This structure is thermally coupled to a dilution refrigerator and has a 1K optics box to minimise stray light. This box will also act as a magnetic field shield for the SQUID amplifiers. Initial concepts are being considered in more detail. One novel feature is the possible use of a 4K "pulse tube cooler" to enable a cryo-free dilution refrigerator to be used. This would save a great deal of time and effort (and consequently money...) during both the lab testing phase and operation on the telescope.

## 4. The road to SCUBA-2

The timeliness of the delivery of SCUBA-2 to the JCMT is critical. For the telescope to remain competitive, in the era leading to new facilities (such as the 50-m LMT in Mexico, the Herschel satellite, and the ALMA interferometer), it is vital that SCUBA-2 be delivered by 2006. Figure 5 highlights some of the current and upcoming facilities that are/will be available for submm astronomy over the next decade. The current plans for SCUBA-2 are to deliver to the telescope before the end of 2005 with one sub-array at each wavelength (i.e. 1600 pixels at 450 and 850 microns). This will give the community as early access to the instrument as possible. Since the production and testing of science-grade sub-arrays will take some time in any case (due largely to limited production line facilities), it has been agreed that a phased delivery of instrument capabilities is the best approach.


*FIGURE 5: The road to SCUBA-2 (and beyond...)*

## 5. Project consortium

The SCUBA-2 Project Consortium is now well established. The overall management of the project, as well as the instrument design, construction, testing and commissioning, are the responsibility of the UK-ATC. NIST are responsible for the TES detectors and SQUID MUX manufacture. Working closely with them will be the SMC, who will carry out the silicon micro-machining of the detector and support structures, and with a specialist company, develop the superconducting bump-bond process for the detector and multiplexer wafers. The Astronomy Instrumentation Group at Cardiff University will test single pixels and prototype electronics, manufacture the filters and dichroic, and participate in the array test and evaluation programme. The Joint Astronomy Centre will be involved in the commissioning of the instrument, and will be largely responsible for infrastructure requirements at the telescope.

## 6. Current milestones

The most critical milestone that SCUBA-2 faces is proving that the proposed array technology will actually work! Hence, there is a major project milestone in October 2002, when it must be proven that a small prototype array (which could be as big as 32 x 32 elements) can be produced. This must prove issues such as detector yield and mechanical robustness, as well as demonstrating thermal, electrical and optical properties close to that designed. In summary, the other major project milestones are as follows:

| | |
|---|---|
| o Optical design PDR | October 2001 |
| o Systems PDR | February 2002 |
| o Array technology CDR | October 2002 |
| o Full prototype (40x40) sub-array | June 2003 |
| o First science-grade 850 sub-array | April 2004 |
| o First science-grade 450 sub-array | November 2004 |
| o Phase I delivery (2 sub-arrays) | October 2005 |
| o Upgrade to full sub-array complement | October 2006 |

## 7. Conclusions

SCUBA-2 represents a major departure from existing submm continuum instruments. Incorporating state-of-the-art technology will allow the realisation of the first large-format "CCD-like" camera for submm astronomy. The science applications for such an instrument are tremendously exciting and very broad-based, ranging from the study of Solar System objects to probing galaxy formation in the early Universe. SCUBA-2 will map large-areas of sky many hundreds of times faster than the current SCUBA. The improved sensitivity and imaging power will allow the JCMT to really exploit periods of excellent weather on Mauna Kea. Undertaking wide-field surveys with SCUBA-2 are vital to fully exploit the capabilities of the new generation submm interferometers. Finally, the new technology has applications beyond SCUBA-2 (optical photon counters, x-ray spectrometers, arrays in space or on even larger telescopes) and thus represents a major strategic investment on behalf of the JCMT funding agencies.

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More information can be found on the SCUBA-2 Homepage: http://www.roe.ac.uk/atc/projects

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**Acknowledgements:**

The SCUBA-2 Project Team consists of:

ATC: William Duncan (Project Director), Wayne Holland (Project Scientist), Trevor Hodson (interim Project Manager), Damian Audley (Instrument Scientist), Dennis Kelly (Systems Analysis and Software Design), Tully Peacocke (Optical Design Engineer), Peter Hastings (Mechanical Design Engineer), Mike MacIntosh (Electronics Engineer), Vicki Ramsay (Project Support)

NIST: Kent Irwin (Project Manager and TES Design), Gene Hilton (MUX Design), Steve Deiker (TES Manufacture and Testing)

SMC: Anthony Walton (Head of Group), Alan Gundlach (Project Manager), William Parkes (Design Engineer: bump bonding), Camilla Dunare (Design Engineer: ion implantation and wafer bonding)

Cardiff Univ: Peter Ade (Project Manager)

Joint Astronomy Centre: Ian Robson (Director), Dean Shutt (Chief Engineer), Tomas Chylek (Mechanical Design Engineer)

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*Gerald Moriarty-Schieven*

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# JAC Employment Opportunities

At the beginning of October, five job opportunities are expected to be posted on the JAC Employment Opportunities web page as well as the other usual media routes. These positions include:

JCMT - Support astronomer/software engineer

JCMT - Support astronomer

JCMT - SCUBA Fellow

JAC - Data reduction software engineer (2 posts)

The deadline to apply for these positions will likely be the end of October. If you, or someone you know, happen to be looking for a position and would like to live in Hawaii, check our "Jobs" page.

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# PATT Application Deadline

**Deadlines for receipt of all JCMT applications for semester 02A is:**

**30 September 2001**

Note that the effective deadline for Canadian proposals is 8am PST October 1 in Victoria, and for UK/International proposals is 8am HST October 1 in Hilo.

**Please read the next article - Electronic Submission Update before filling in your application forms for the forth-coming semester. In particular Canada requests electronic applications only, no paper submissions.**

To ensure prompt processing, please ensure that your applications are sent to the correct establishment. Applications for JCMT time should be submitted to the national TAG of the Principal Investigator (PI) or, if the PI is not from one of the 3 partners, to the national TAG of the first named co- investigator on the application who is from one of the partners. International applications (those with no applicants from one of the partners) should be submitted to the PATT Secretariat at PPARC, Swindon. Members of the JAC staff in Hawaii count as International unless they are the PI on an application, when it should be forwarded to the appropriate national TAG.

**Country paying salary of Principal Investigator**

| Canada | Netherlands | UK or International |
|---|---|---|
| Director-General's Office, | Dr. Frank Briggs, | PATT Secretariat, |
| National Research Council of Canada, | Kapteyn Astronomical Institute, | PPARC, |
| 5071 West Saanich Road, Victoria, BC, | Postbus 800, | Polaris House, |
| CANADA V8X 4M6 | NL-9700 AV Groningen, | Swindon, SN2 1ET, |
| | NETHERLANDS | UNITED KINGDOM |

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JCMT image here

# Weather Statistics for Semester 00B

The following tables present the weather loss for semester 00B. For losses dut to faults see the the Operational Stats. A more detailed description of how these tables are created is also available here.

| Month | Available | Extended | Lost to weather | | Lost to weather | |
|---|---|---|---|---|---|---|
| | | | Primary | % | Backup | % |
| Aug | 478.0 | 21.9 | 198.3 | 41.5 | 83.6 | 17.5 |
| Sep | 480.0 | 10.6 | 214.5 | 44.7 | 99.3 | 20.7 |
| Oct | 488.0 | 9.4 | 254.3 | 52.1 | 120.2 | 24.6 |
| Nov | 477.5 | 31.5 | 160.1 | 33.5 | 121.5 | 25.4 |
| Dec | 468.0 | 22.1 | 71.1 | 15.2 | 30.9 | 6.6 |
| Jan | 496.0 | 25.6 | 69.5 | 14.2 | 34.8 | 7.1 |
| | | | | | | |
| Totals | 2887.5 | 121.1 | 967.8 | 33.6 | 490.3 | 17.0 |

*Iain Coulson*

JCMT image here

# Weather Statistics for Semester 01A

The following tables present the weather loss for semester 01A. For losses dut to faults see the the Operational Stats. A more detailed description of how these tables are created is also available here.

| Month | Available | Extended | Lost to weather | | Lost to weather | |
|---|---|---|---|---|---|---|
| | | | Primary | % | Backup | % |
| Feb | 448.0 | 14.3 | 149.1 | 33.9 | 127.2 | 28.9 |
| Mar | 488.0 | 32.3 | 118.0 | 24.2 | 49.3 | 10.1 |
| Apr | 480.0 | 19.4 | 202.4 | 42.9 | 61.7 | 13.1 |
| May | 478.5 | 10.5 | 119.3 | 24.9 | 16.3 | 3.4 |
| Jun | 464.0 | 7.0 | 296.8 | 64.0 | 183.2 | 39.5 |
| Jul | 488.0 | 11.2 | 246.4 | 50.5 | 163.3 | 33.5 |
| | | | | | | |
| Totals | 2846.5 | 94.7 | 1132.0 | 39.8 | 601.0 | 21.1 |

*Iain Coulson*

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# JCMT Heterodyne Instrumentation Status

The current state of the JCMT heterodyne instruments, their availability on the telescope and their sensitivities and other observational parameters can always be located on the relevant pages within the JCMT World-Wide Web site:

**Status** of current receivers.

**RxA3**

**RxB3**

**RxW**

**Heterodyne Polarimetry**

**DAS Spectrometer guide**

**DAS "non-standard" configurations**

**Heterodyne Integration Time Calculator** This facility is a web-based and stand-alone perl script for estimating the required integration time (or rms noise) for heterodyne observations.

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# Lethbridge Fourier Transform Spectrometer

It is likely that the Lethbridge FTS will be available for use during semester 02A. Further information is available at:

http://home.uleth.ca/phy/naylor/FTS.html

The Lethbridge group welcomes scientific collaborations with other JCMT users. Please contact Prof. D.A. Naylor (naylor@uleth.ca) to arrange collaborative efforts.

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# SPIFI: The South Pole Imaging Fabry-Perot Interferometer

SPIFI is a direct detection, imaging Fabry-Perot interferometer designed for use in the submillimeter band (200 to 650 microns), especially the 350 and 450 micron windows available to the JCMT. SPIFI's detector is a 5 x 5 element monolithic silicon bolometer array cooled to 60 mK in an adiabatic demagnetization refrigerator. SPIFI uses free standing metal mesh Fabry-Perot interferometers to deliver spectroscopic images at velocity resolutions up to 30 km/s over the entire array. The velocity resolution is continuously adjustable from 300 to 30 km/s in a few minutes time at the telescope. Higher velocity resolutions (better than 15 km/s) are possible for the inner 9 pixels. The Winston cones coupling radiation to SPIFI's bolometers have 6.1" (~ lambda/D at 450 microns) circular entrance apertures and are arranged on a 7.0' square grid, so that SPIFI images a 35" x 35" field of view at the diffraction limit of the JCMT telescope.

SPIFI may be available for use during the semester. Current best estimates of sensitivities and other parameters will be posted on the web page at the Cornell Astronomy Department Site.

First light for SPIFI on the JCMT in April 1999. A report on this event was published in the March 2000 JCMT Newsletter.

The Cornell group welcomes scientific collaborations with other JCMT users. Please contact Prof. G.J. Stacey at Cornell University (stacey@astrosun.tn.cornell.edu) to arrange collaborative efforts.

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# Max-Planck-Institut 800 GHz Instrument

The MPIfR/SRON heterodyne spectrometer (MPIRE) for the 350 micron atmospheric window (E-band) has been successfully installed and commissioned at the JCMT in April 2000. The figure at the top shows the integrated system in the Cassegrain cabin. The spectrometer consists of a single-channel fixed-tuned waveguide mixer with an SIS NbTiN junction fabricated at the University of Groningen. The current tuning range of the mixer is 790-840 GHz. Among the most important lines within this band are the transitions of CO J=7-6 [807 GHz], [CI] 3P2-3P1 [809 GHz], HCO+ J=9-8 [802 GHz], and HCN J=9-8 [797 GHz].

The double-sideband (DSB) receiver temperature is in the range 500 - 800 K, the highest sensitivity is around 800 - 810 GHz. Only DSB operation is possible. The maximum available bandwidth for the DAS is currently 920 MHz. The measured single-sideband system temperatures at the JCMT are around 10,000 K or much less under good submillimetre weather conditions (tau_225 GHz<0.05). Preliminary analysis yields a main beam efficiency eta_mb~0.15.

The system is currently on loan from MPIfR and available in semester 01B for use by the JCMT community on a collaborative basis. Astronomers interested in using it should contact Ronald Stark (stark@mpifr-bonn.mpg.de) to arrange collaborative efforts. The instrument will stay at JCMT for an extended time during which a continuous improvement of its performance is planned.

Further details can be found at:

http://www.mpifr-bonn.mpg.de/div/mm/tech/mpire.html

Observers interested in using it should contact Dr. Ronald Stark (stark@mpifr-bonn.mpg.de) to arrange collaborative efforts.

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*Modification Author: Gerald Moriarty-Schieven (gms)*

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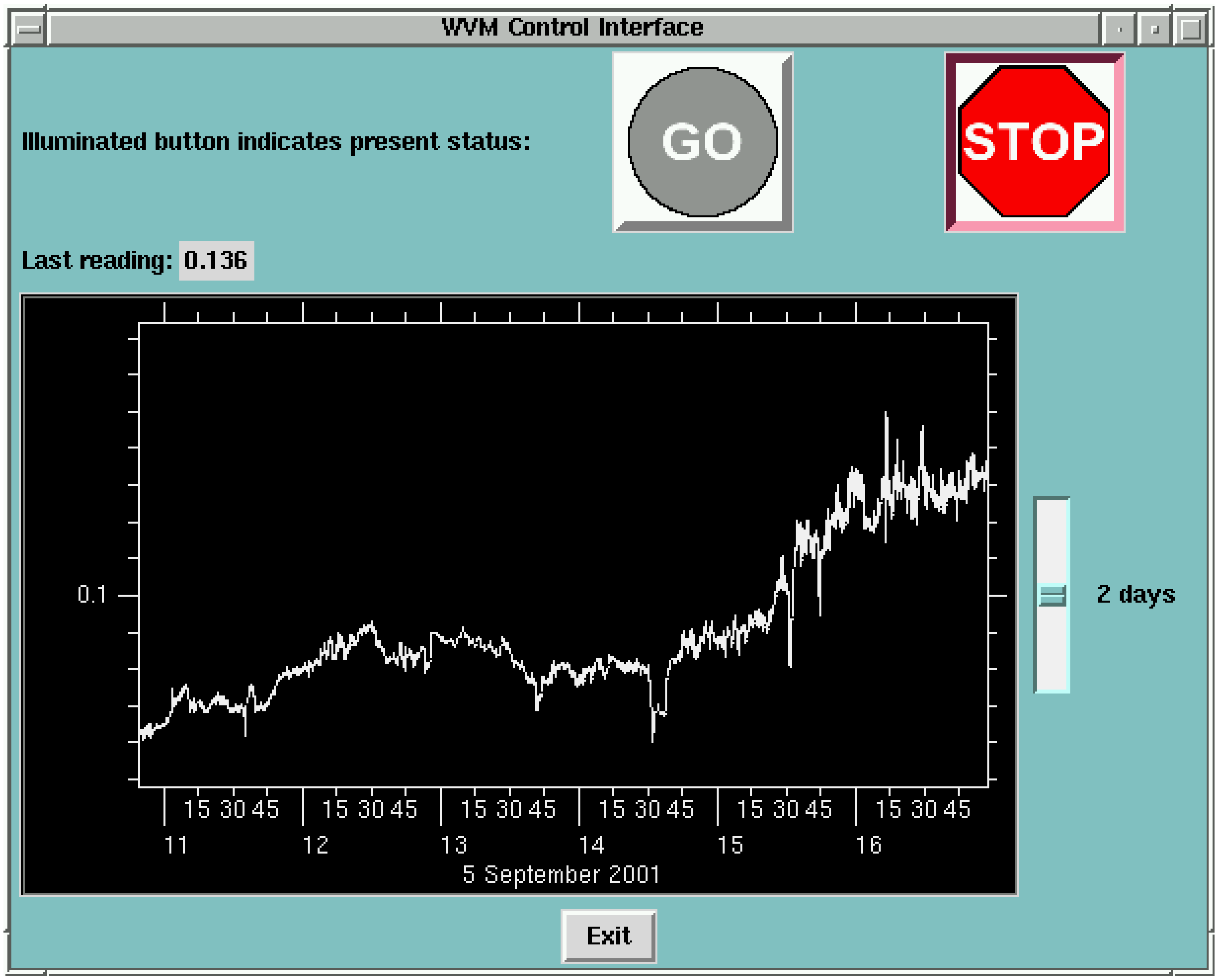
# The JCMT 183GHz WVM

Since the summer of 2001 the JCMT has been reguarly using a cabin mounted Water Vapour Monitor (WVM) provided to the JCMT by MRAO. Built as a thesis project by Martina Wiedner (under the supervision of Richard Hills) it works by looking at the 183GHz water vapour line using a three channel double side band receiver. The three channels enable it to provide accurate measurements in conditions ranging from very dry to very wet. By using a small pickup mirror mounted just above and to one side of the main JCMT tertiary mirror it looks almost exactyl along the same line of sight that the primary instrument being used is. This feature is at its most useful in variable conditions where the CSO tau may not be giving reliable readings (if, for example, a new weather front is approaching from one horizon). With a sampling rate of 1 reading per 6 seconds it is easily able to detect individual clouds (or 'blobs' of water) passing overhead. This semester we are investigating the possibility to use it to correct the SCUBA photometry data.

The picture above shows the WVM mounted above receiver W with the pickup mirror mounted above the TMU.

The screen shot shown below is the current user interface which enables it to be started and stopped and displays recent data collected. All the data collected over the last few months has been archived.

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*[Robin Phillips]()*

# Tau, Seeing, and Sensitivities

When you are writing your proposals (and observing templates, should you be awarded telescope time or fallback time), remember that there are web-based tools to assist you with calculating RMS noise of your observations.

The SCUBA integration-time calculator is available here.

The heterodyne integration-time calculator is available here.

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High quality projects that can be done in poor weather (band 4/5) are always in demand. The opacity in the A-band window is typically a factor of 4 less than at 850 microns, so one could argue that working with reciever A in tau-cso = 0.3 is similar to working with SCUBA 850 in grade 2 conditions - certainly excellent results can be achieved. The following table should give you some idea of whether your project could be done with receiver A in grade 4 or 5 weather, and just how bad the weather can be before it's pointless to continue.

> If tau is 0.15 you get a certain rms in one hour.
>
> If tau is 0.20 you'll get the same rms in 1.4 hours
>
> If tau is 0.25 you'll get the same rms in 2.0 hours
>
> If tau is 0.30 you'll get the same rms in 2.6 hours
>
> If tau is 0.35 you'll get the same rms in 3.2 hours
>
> If tau is 0.40 you'll get the same rms in 4.0 hours.

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Note that *tau* and *seeing* data can now be downloaded from the archive for any date/time from 1997 onwards. Click here for more information.

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*Gerald Moriarty-Schieven*

# Engineering Console Upgrade - Oct 2001

The electronics in the carousel engineering console (CEC) have become increasingly unreliable and adequate spares for many components do not exist. The planned upgrade, which will shut the telescope down from 5-7 November, will result in a significant increase in facility reliability and maintainability. The CEC provides the logic for the roof and door safety interlock chain, is the main control for operation of the roof, doors and ventilation louvers, and contains electronics that condition the demand signal to the carousel drive system.

The CEC will be replaced with a modern Allen Bradley Programmable Logic Controller (PLC). The PLC can be programmed to duplicate the relay logic currently implemented in the CEC. In addition it provides an LCD display that will be much more user friendly than the existing system. The unit is a standard package already supported by JAC ETS with units in service controlling UKIRT dome and plant room systems.

Reliability of CEC controlled systems will be greatly improved as the current analog/digital discrete component system will be replaced in total by the solid state electronics in the PLC. It will also provide the capability to open the facility roof and doors, as well as control the ventilation louvers, remotely. This is an essential element of the future manned startup/remote observing JCMT operation model.

In concert with the CEC work, the slew speed of the carousel will be increased from the current .6 deg/sec to the original design value of 1.5 deg/sec. This will improve observing efficiency through a reduction in the overhead required to slew between sources. The control signal to the carousel will also be conditioned in a more rational manner through elimination of the redundant signal conditioning in the CEC.

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*Dean Shutt - Chief Engineer JAC*

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# Magnetic Fields in the Gas Feeding the Galactic Centre

**J.S. Greaves & W.S. Holland** - *ROE/ATC*

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A magnetic field near the centre of our Galaxy might be very important for gas dynamics - in particular, it could help channel material falling onto the (candidate) black hole at the centre, Sgr A*. There is good evidence for strong organised magnetic fields, both from Zeeman data (Plante, Lo & Crutcher 1995) and dust polarization (Hildebrand et al. 1993, Novak et al. 2000, and recent SCUBA polarimetry by Chrysostomou et al.). However, the view towards the inner few parsecs of our Galaxy is very complicated - so these techniques might mix up different magnetic field components from any of the clouds along the 8.5 kpc line of sight!

Our solution to this was to use spectral line polarimetry, and thus to separate out all the foreground clouds by velocity. Small polarizations arise in molecular lines because population imbalances among the magnetically-split rotational levels can produce different emission in the planes perpendicular or parallel to the magnetic field (Goldreich & Kylafis 1981). Spectro-polarimetry has been offered at the JCMT for several years, but always as a non-standard observing mode, and it is only now that the data reduction techniques have become streamlined and easy to use.

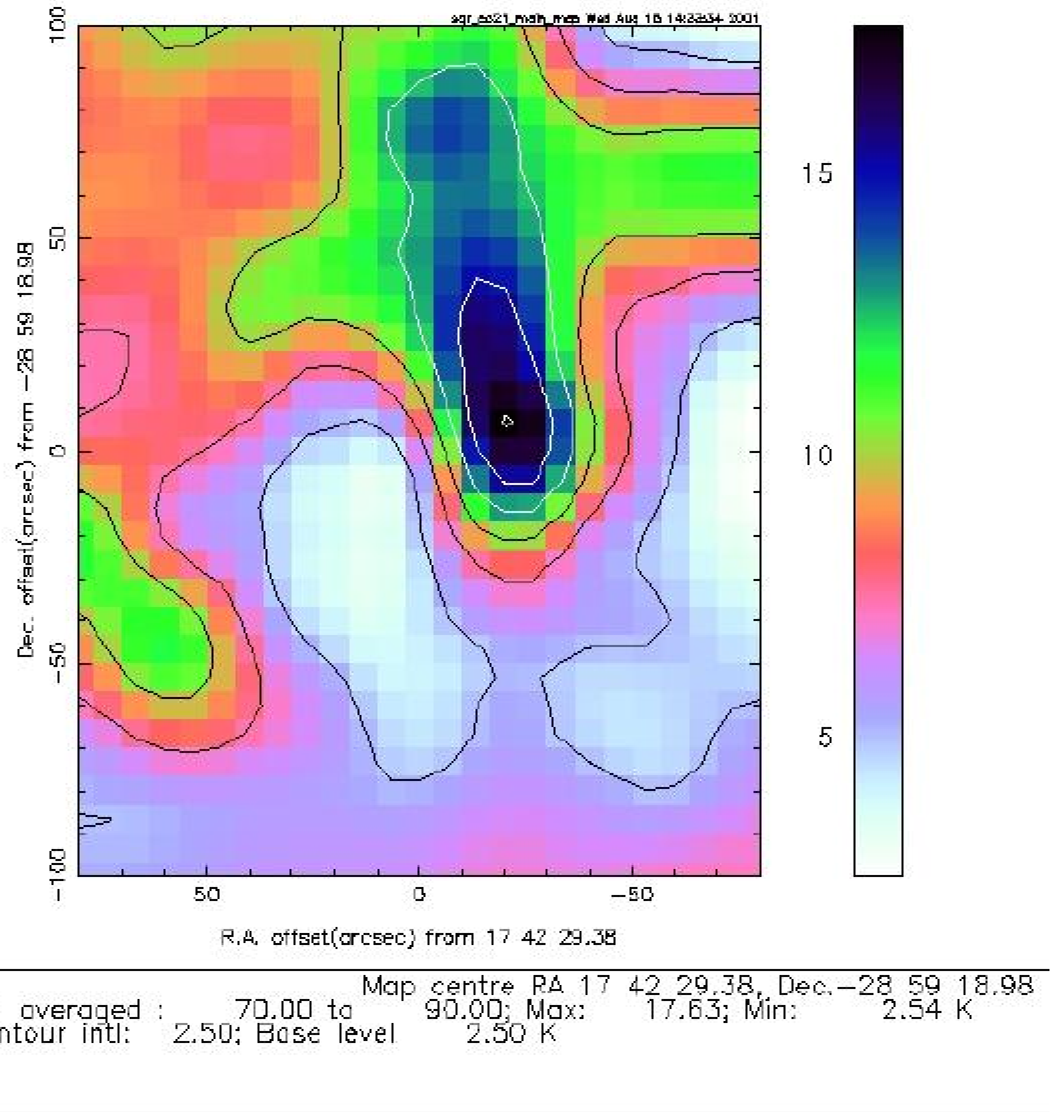


*Figure 1: CO 2-1 integrated intensity toward the Galactic Centre.*

These results are from our observations of the Galactic Centre in CO J=2-1. Figure 1 shows one of the main gas streamers feeding into the Galactic Centre, at an LSR velocity of +80 km/s. This streamer runs from the north end of the circumnuclear `2 pc ring' towards Sgr A* at the centre of the map. Figure 2 shows the polarization results for a point at the top of this streamer (dRA,dDec = 0,+75"): the red line is the total intensity CO spectrum, the green line is the polarization percentage spectrum (multiplied by 10 for clarity), and the blue line is the polarization direction (in degrees). Although there are some variations among the positive velocity features, the polarization direction in the streamer gas (+80 km/s) is quite similar to the other clouds, for example the '2 pc ring' which has a velocity at this point of about +65 km/s. The net direction is about -10 degrees, and is perpendicular to dust polarization (+77 degrees: Hildebrand et al. 1993). The only dramatically different result is for a second streamer at -20 km/s, where the polarization direction diverges by about 60 degrees.

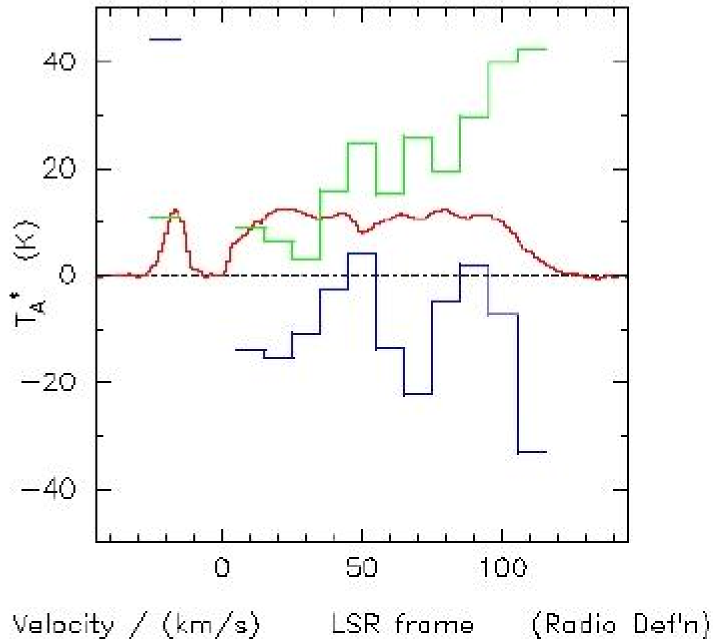


*Figure 2: Polarization as a function of velocity at one position toward the Galactic Center (dRA,dDec = 0,+75"). Red line: CO spectrum; green line: polarization percentage spectrum (multiplied by 10 for clarity); blue line: polarization direction (in degrees).*

Thus there seems to be a largely uniform magnetic field direction for the gas clouds orbiting around and infalling onto Sgr A*. Also, the inferred magnetic field direction is close to north-south - the configuration required to help material fall onto the black hole. In fact, our full data set of four positions in the north-south streamer suggests slight curvature of the magnetic field, roughly following the ionized gas 'mini-spiral' (Jackson et al. 1993). Spectro-polarimetry has thus given us more robust evidence for this magnetic configuration than did previous observing techniques - and has many other potential applications for gas clouds with velocity structure. The 'ROVER' project (http://www.jach.hawaii.edu/~jsg/rover/rover.html) aims to bring a new spectro-polarimetry upgrade to the JCMT in about 2 years time.

References:


Goldreich P. & Kylafis N.D., 1981, ApJ 243, L75

Hildebrand R.H. et al., 1993, ApJ 417, 565

Jackson J.M. et al., 1993, ApJ 402, 173

Novak G. et al., 2000, ApJ 529, 241

Plante R.L., Lo K.Y. & Crutcher R.M., 1995, ApJ 445, L113


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*Gerald Moriarty-Schieven*

# Distribution of dust in NGC 4449

C. Böttner, U. Klein, N. Neininger (RAIUB), S. Kohle (Mevis) & C. Henkel (MPIfR Bonn)

NGC 4449 is a prototypical dwarf irregular galaxy of the Magellanic type, located at a distance of 3.7 Mpc (Bajaja et al., 1994). It is the best studied low-mass galaxy beyond the Magellanic Clouds, with a host of data available over essentially the whole electromagnetic spectrum (citing even the most relevant papers would be beyond the scope of this contribution). The only gap of missing information was left in the mm/submm window (exept for measurements at selected positions), which was recently filled by completely mapping the CO line (IRAM 30-m) and the dust continuum (JCMT).

Low-metallicity galaxies such as NGC 4449 are generally deemed dust-poor, but quantitative answers to this conjecture have not been given so far. We have therefore embarked on a project to fully map the molecular gas and dust in this template galaxy. SCUBA observations were carried out in January 1999. A total integration time of 2 hours was obtained to yield final maps at 850 and 450 um, respectively. The dust emission is clearly seen in both maps. In Fig.1 we show contours of the 850 um continuum, superimposed onto a grey-scale representation of the Halpha emission. It is evident that the strongest dust emission follows the distribution of intense star formation (as expected). There is also significant dust emission away from the star-forming regions, but this is also accompanied by CO radiation. Fig.2 shows that there is an overall correspondence of dust and molecular gas, though naturally not obeying a one-to-one relation. The big caveat here is that the CO emissivity depends on local excitation conditions (stellar radiation field, X-ray and CR heating). However, since dust and molecular hydrogen are closely coupled, the data presented here provide an important basis for a study of the molecular gas. This is facilitated by the comprehensive data base that we have at our disposal: HI, 850 and 450 um, CO(1-0) and (2-1), radio continuum at several frequencies, X-rays, H alpha, optical and UV.

A couple of relevant numbers resulting from our ongoing study are worth being mentioned here. The total flux densities at 850 and 450 um are $S_{850}$ =1.5 +/- 0.2 Jy (after corrections for CO) and $S_{450}$ =16.5 +/- 3.3 Jy, respectively. We fitted a three-component dust model to the FIR distribution (Fig.3) and get temperatures of 16, 38 and 170K, resulting in a total dust mass of $M_d \sim 1.7 \cdot 10^6$ $M_o$ , where an absorption coefficient of $k_{d850}$ = 1.5 $cm^2$ $g^{-1}$ has been adopted. The CO luminosity of $L_{CO} = 7.9 \cdot 10^6$ K km $s^{-1}$ $pc^2$ leads to a total $H_2$ mass of $M_{H2} = 4.4 \cdot 10^8$ $M_o$ , with a conversion ratio of CO intensity to $H_2$ columm density of $X_{CO} \sim 14$ $X_{gal}$ , with $X_{gal} = 2.8 \cdot 10^{20}$ $cm^{-2}$ (K km $s^{-1})^{-1}$ (Kohle 1999). Combining this with the HI mass in the same integration area, this yields a total gas mass of $M_{HI+H2} = 6 \cdot 10^8$ $M_o$ . The resulting gas-to-dust ratio is ~ 400. This is a factor of ~ 3 higher than the canonical value of ~ 150 (e.g. Schmitd & Boller, 1993) for the Milky Way. It is in accord with the lower metallicity of NGC 4449, viz 12+log(O/H) = 8.3 (Lequeux et al., 1979), a factor of ~ 3 below the Milky Way value.

Finally, we point out that studies of nearby low-metallicity galaxies (i.e. dwarfs) may provide important clues to a proper interpretation of galaxy observations at cosmological redshifts, hence to a better understanding of galaxy evolution.

**Acknowledgements**

We are grateful to Gerald Moriarty-Schieven for performing the observations.

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**Figures**

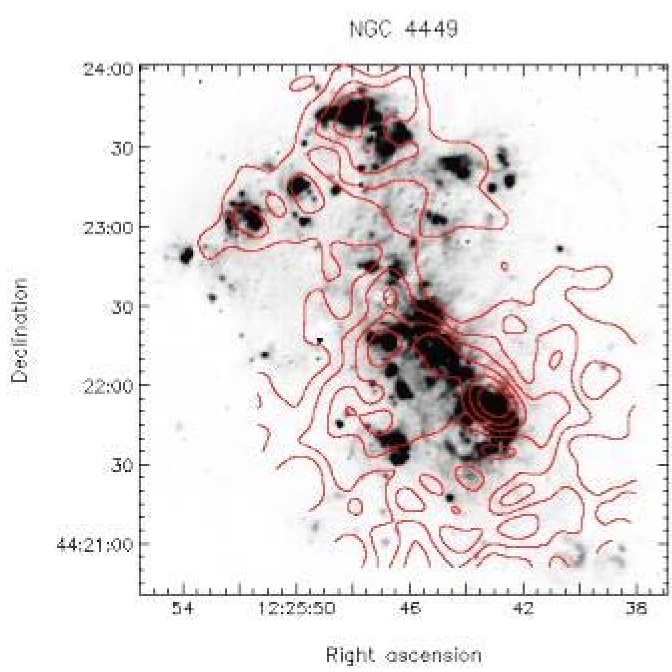


Fig. 1.: 850 um SCUBA contour map of NGC 4449, superimposed onto an Halpha image. Contours are 6, 11, 16, 21, 26 and 31 mJy/beam. The rms noise level of the 850 um map is 6 mJy/beam. (Coordinates refer to equinox 1950)

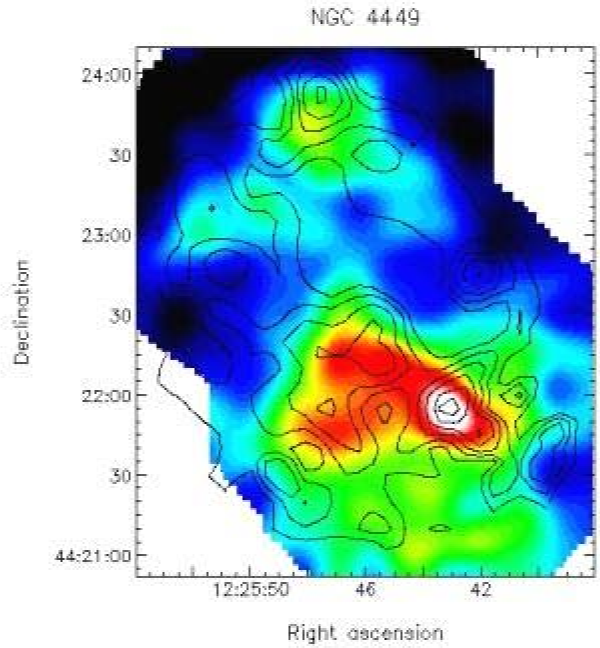


Fig. 2.: 850 um map of NGC 4449 (colour, smoothed to 22"), with CO(1-0) contours superimposed. Contours are 0.15, 0.25, 0.35, 0.45, 0.55, 0.60 K km $s^{-1}$

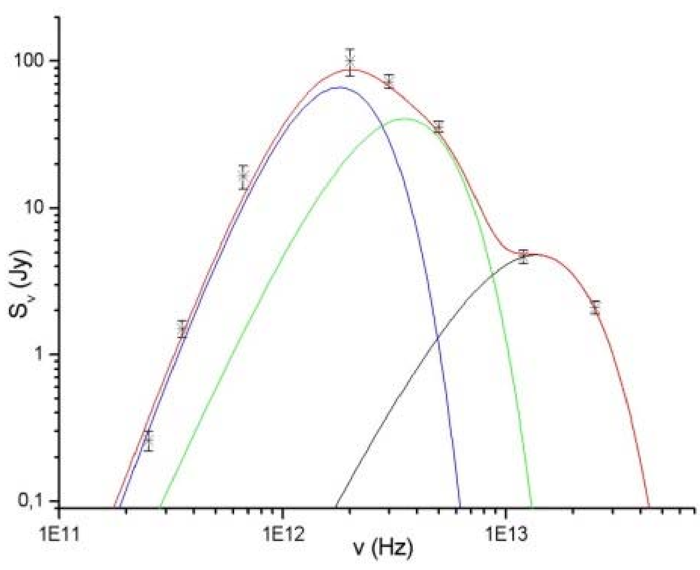


Fig. 3: The integrated FIR spectrum of NGC 4449. The fitted lines correspond to dust components with temperatures of 16 K, 38 K and 170 K. The quantities for lambda <= 100 um are from Hunter et al. (1986), the value at 150 um is from Thronson et al. (1987) and the 1200 um flux is from Kohle (1999)

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# The SCUBA 8-mJy Survey

**Susan Scott, Jim Dunlop, Andy Lawrence, John Peacock, Omar Almaini, Bob Mann**
*Edinburgh IfA*

**Rob Ivison**
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**Michael Rowan-Robinson, Matt Fox, Andreas Efstathiou**
*Imperial College, London*

**Steve Serjeant**
*Kent*

**Seb Oliver**
*Sussex*

**Andrew Blain**
*Cambridge IfA*

**Molcolm Longair**
*Cavendish Laboratory*

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## Introduction

Over the past four years, deep sub-millimetre surveys carried out using SCUBA on the JCMT (Smail et al. 1997, Hughes et al. 1998, Barger et al. 1998 & 1999, Blain et al. 1999, Eales et al. 1999 & 2000), have revealed the extreme importance of dust in the determination of the global star-formation history of the Universe. Observations at optical/UV wavelengths have implied that the star-formation rate (SFR) rises steeply as a function of redshift between z=0 and z=1 (Lilly et al. 1996), peaking at 1 < z < 1.5, and declining to values comparable to the present day at ~z=4 (Madau et al. 1996). However in heavily dust-enshrouded star-forming regions, much of the optical/UV radiation emitted by the young stars is absorbed, leading to the possibility that a significant amount of star formation, particularly at high-redshift, may have been missed in these wavebands.

In order to quantify the star-formation density contributed by such highly-obscured objects, we must observe directly the rest-frame far-infrared (FIR) emission from the heated dust, which at redshifts greater than z~1 is shifted into the sub-millimetre waveband. Furthermore, the steep spectral index of the thermal emission longward of the peak at ~100um results in a sufficiently large negative K-correction that the dimming effect of increasing cosmological distance is effectively cancelled over a wide range in redshift. Consequently, for a galaxy with fixed intrinsic FIR luminosity we would expect to observe approximately the same 850 um flux-density for an object at z=8 as at z=1.

## The SCUBA 8-mJy Survey at 850 um

The `SCUBA 8-mJy Survey' (Scott et al. 2001, Fox et al. 2001, Lutz et al. 2001, Almaini et al. 2001, Ivison et al. 2001) is a wider-area, somewhat shallower survey than its earlier counterparts, covering a total area of 260 arcmin$^2$, evenly split over two regions of sky (the ELAIS N2 and Lockman Hole East - figs. 1 and 2 respectively), and reaching a typical rms noise level of sigma(850)~2.5 mJy/beam. This survey has three key advantages over previous sub-millimetre surveys. Firstly, the relatively bright flux-density limit facilitates follow-up with existing instrumentation which will eventually yield an accurate astrometric position (via the VLA or IRAM PdB) for every source. Secondly, the lower source-density at ~8 mJy means that source confusion is much less of a problem. Finally, this survey is optimally designed for the detection of the most luminous starburst galaxies at high redshift, with SFRs > 1000 Mo yr$^{-1}$. Our extensive follow-up programme with thus allow us to test the suggestion made by several authors (e.g. Dunlop 2001) that such objects are the progenitors of the present-day massive-elliptical population.

We have used a maximum-likelihood technique to measure the statistical significance of each peak in our maps, detecting 19 sources with S/N > 4, 38 with S/N > 3.5, and 72 with S/N > 3 (Scott et al. 2001). Based on these detections and extensive simulations our best estimate of the cumulative source count at $S_{850}$ > 8 mJy is $320^{80}_{-100}$ deg$^{-2}$, consistent with a range of models involving strong evolution of the dust-enshrouded starburst population. These objects have inferred star-formation rates in excess of 1000 Mo$^{-1}$, enshrouded in $10^8$-$10^9$ Mo of dust. Assuming that the majority of sources lie at z > 1.5, this result implies that the co-moving number density of high-redshift galaxies forming stars at a rate in excess of 1000 Mo yr$^{-1}$ is $10^{-5}$ Mpc$^{-3}$, with only a weak dependence on the precise redshift distribution. This is a very interesting number, since it corresponds to the number density of massive ellipticals with L > 3-4 $L_*$ in the present-day universe, and is also the same as the co-moving number density of comparably massive, passively-evolving objects in the redshift band 1 < z < 2 inferred from recent surveys of extremely red objects (EROs). Thus while the brightest sub-millimetre sources uncovered by this survey contribute only ~10% of the sub-millimetre background, they can plausibly account for the formation of all present-day massive elliptical galaxies. A key test of this picture is to determine whether the bright SCUBA population is at least as strongly clustered as are the EROs at intermediate redshifts (Daddi et al. 2001). A first attempt at such a test has proved inconclusive due to the small numbers of significant sources (>3.5 sigma) detected in our survey areas, but there are some initial indications of clustering on scales of 1-2 arcminutes, particularly in the ELAIS N2 field.

## Multiwavelength Follow-up

Both the Lockman Hole East and ELAIS N2 have a vast quantity of multi-wavelength data available for follow-up studies. The faintness of the SCUBA population means that spectroscopically-determined redshifts remain a distant goal for all but a handful of the 850 um sources, but we can use the radio-to-infrared spectral energy distribution (SED) to constrain the allowed redshift range. It is then possible to identify potential optical/IR counterparts consistent with both the position of the SCUBA source and with the SED-based redshift constraints and through deep radio or millimetre interferometry establish the correct identification (if any.

In Fox et al. (2001) we consider 19 of our most significant sources in this way. Exploiting the parallel SCUBA 450um observations, in combination with radio and ISO data, our derived SED-based redshift constraints suggest that all of these sources are at z > 1, with at least 50% at z > 2. Deep *K*-band imaging currently exists for 8 of these 850um sources, of which 5 have revealed a potential ERO counterpart to the SCUBA source. In the case of our most significant Lockman Hole East source, Lockman850.1 (Lutz et al. 2001), an accurate astrometric position yielded by the IRAM PdB interferometer has allowed us to make a solid *K*-band identification. The near-infrared counterpart (fig. 3) is an extended (20-30 kpc), clumpy, and extremely red object (*I - K > 6.1*). The SED suggests it to be a dusty star forming object at a redshift of about 3 (2-4). Its SFR and near-infrared properties are consistent with Lockman850.1 being a massive elliptical in formation.

Over the next two years we aim to obtain comparably detailed redshift and morphological information on a substantial fraction of our brightest sources. In particular, very deep VLA imaging is already providing greatly-improved redshift constraints (shortly to be published by Ivison et al. 2001), while deep near-infrared imaging of our sources with Gemini is currently scheduled as the top-ranked UK proposal with NIRI on Gemini for the current semester.

## The relationship of SCUBA and Chandra sources

The relationship between the hard X-ray and sub-millimetre populations is explored in Almaini et al. (2001) using deep Chandra observations of the ELAIS N2 field. In agreement with other recent findings (eg Barger et al. 2001), we confirm that the direct coincidence is small; 1/17 SCUBA sources with S/N > 3.5, or 2/36 with S/N > 3 having a significant X-ray detection consistent with active galactic nucleii (AGNs). In one other case where sub-arcsecond VLA and *K*-band positions are available, a weak X-ray flux is measurable but consistent with starburst activity. Unless the central engine is obscured by Compton-thick material with a low (< 1%) scattered component, this implies that the majority of SCUBA sources are not powered by AGN. Furthermore, the detection of only ~5% of the SCUBA sources by Chandra would require that the typical obscuration is almost isotropic, inconsistent with a unified AGN scheme.

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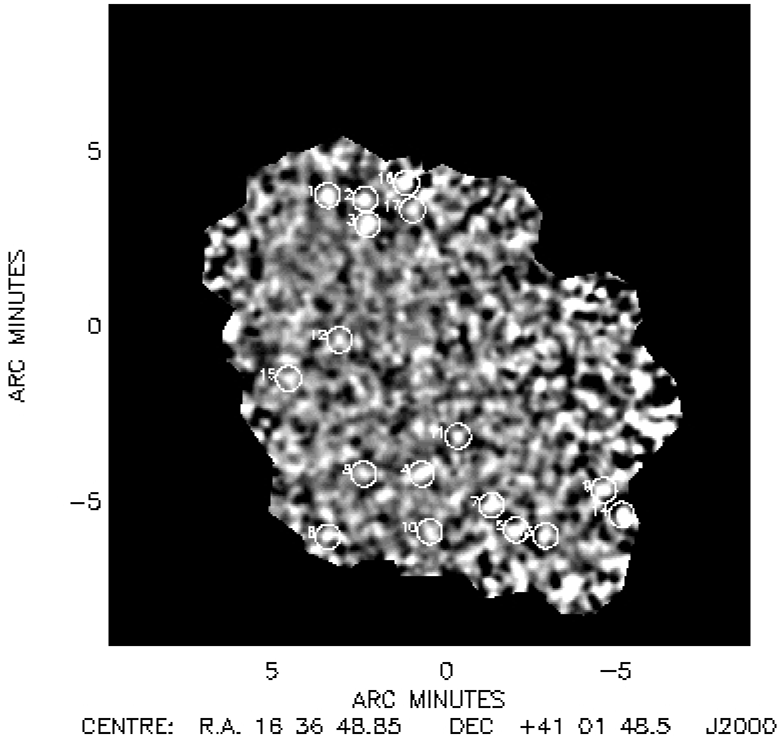
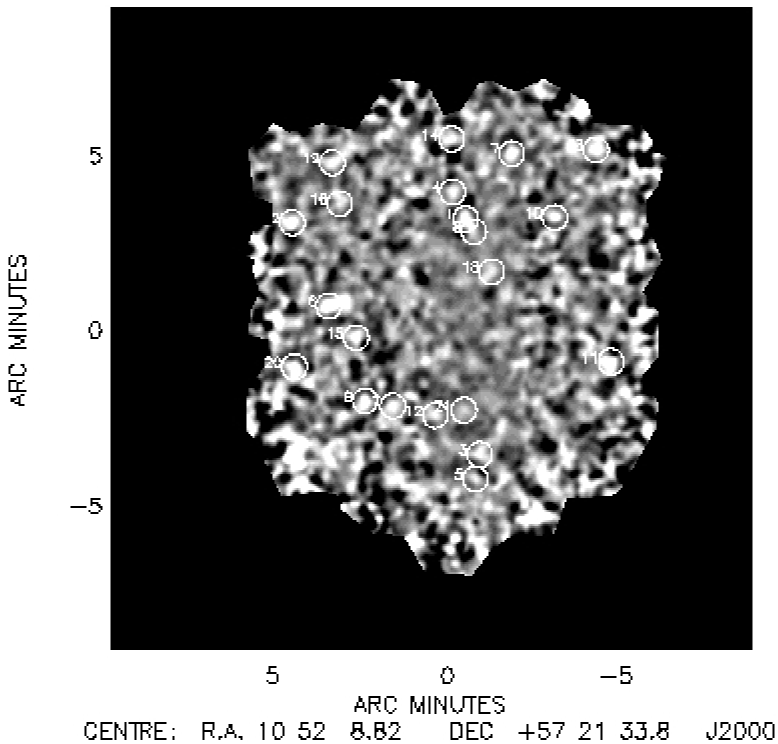
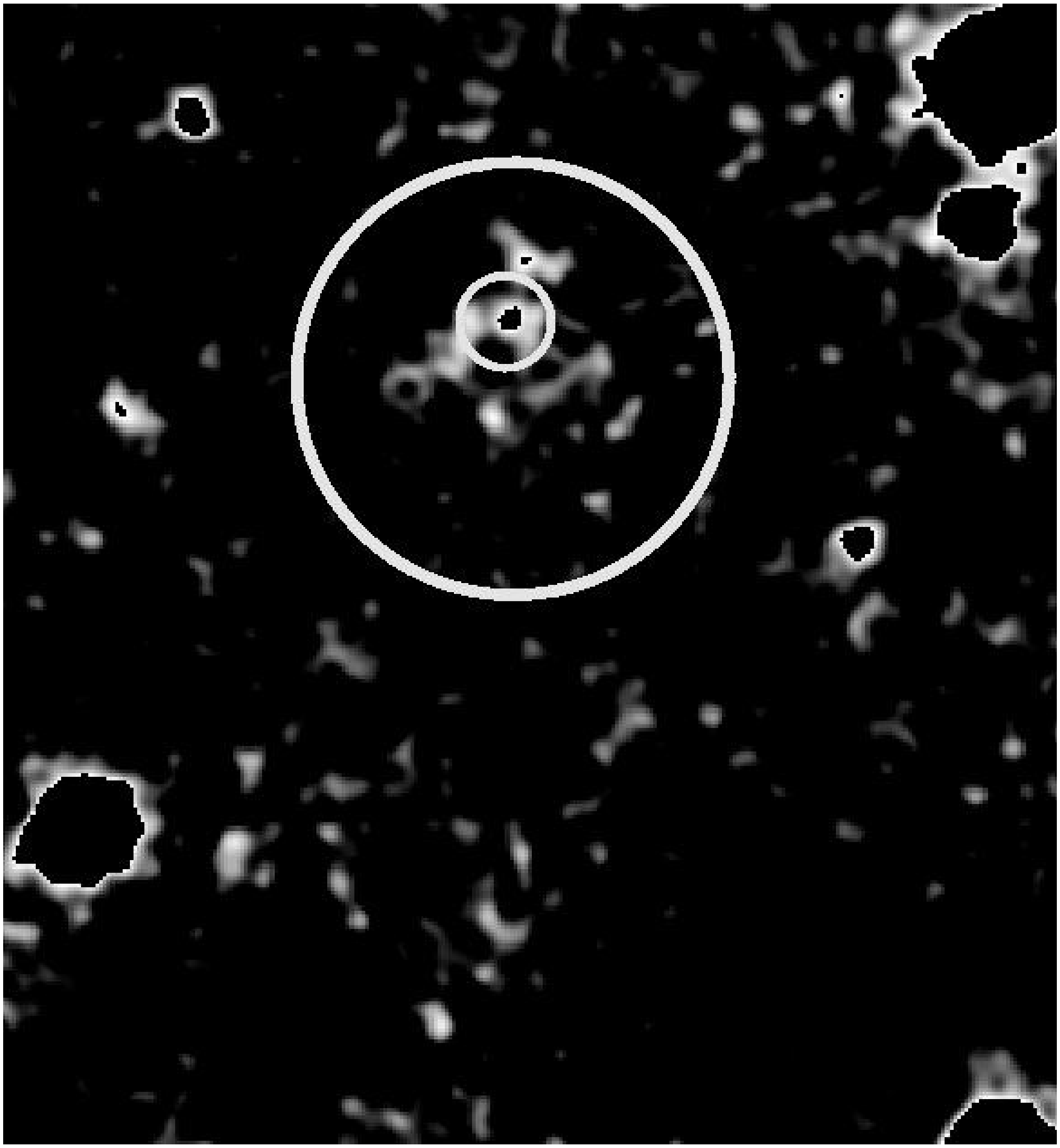



Figure 1: The 850um image of the ELAIS N2 field, smoothed with a beam-size Gaussian (14.5 arcsec FWHM). The numbered circles highlight those sources found at a significance of >3.5sigma in order of decreasing significance.




The 850um image of the Lockman Hole East field, smoothed with a beam-size Gaussian (14.5 arcsec FWHM). The numbered circles highlight those sources found at a significance of >3.5sigma in order of decreasing significance.



The figure shows a 30 x 30 arcsec region of a deep (6-hour integration on UKIRT + UFTI) *K*-band image of the field in the vicinity of the $S_{850um}$um = 10.5 mJy source Lockman850.1. The position of the SCUBA source is marked by the large (10-arcsec diameter) circle, while the position of the 1.3mm source detected in follow-up observations with the IRAM PdB interferometer is marked by the small (2-arcsec diameter) circle (Lutz et al. 2001). The SCUBA/IRAM source can be unambiguously identified with the brightest of a group of (apparently connected) compact peaks with *K*~21.4. All of these faint peaks are too red to be detected in the deepest available *I*-band image of this field reaching *I*~27.5.

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# A SCUBA survey of the NGC 2068/2071 protoclusters

**Frédérique Motte** (*CalTech*) & **Philippe André** (*Saclay*)

We have used SCUBA on JCMT to conduct a submillimeter dust continuum survey of the protoclusters NGC 2068 and NGC 2071 in Orion B (Motte, André, Ward-Thompson, & Bontemps 2001, A&A, 372, L41). The region mapped at both 850 um and 450 um is ~32'x18' in size (~4x2pc) and consists of filamentary dense cores which break up into small-scale (~5000AU) fragments, including 70 starless condensations and 5 circumstellar envelopes/disks (see Fig. 1). The starless condensations appear to be virialized and pre-stellar in nature. Their mass spectrum, ranging from ~0.3Mo to ~5Mo, is reminiscent of the stellar initial mass function (IMF). In agreement with earlier studies by Motte, André, & Neri (1998), Testi & Sargent (1998), and Johnstone et al. (2000), this result strongly suggests that pre-collapse cloud fragmentation plays a major role in shaping the IMF (see also review by Motte & André 2001, in *From Darkness to Light*, ASP Conf. Ser., vol. 243, p. 301, astro-ph/0102376).

The pre-stellar condensations of NGC 2068/71, as well as those identified at 1.3 mm by Motte et al. (1998) in the rho Oph protocluster, follow a M ~ R mass-size relation which is consistent with that of self-gravitating isothermal structures (such as critical Bonnor-Ebert spheres, cf. Fig. 2). Note that this differs from the $M \sim R^2$ mass-size relation of the clumps found by Johnstone et al. (2000) in a related 850 um SCUBA survey of rho Oph. The latter is similar to the mass-size relation of CO clumps and is consistent with the fractal, turbulent nature of molecular clouds. The difference arises from the use of different clump-finding algorithms. While Johnstone et al. used the *Clumpfind* algorithm (Williams et al. 1994) which does not discriminate between spatial scales, we employed a multi-resolution wavelet analysis to select only gravitationally-bound starless fragments seen on the same scales as protostellar envelopes (diameter < 10000 AU in NGC 2068/71). We believe that our method is more appropriate to identify the direct progenitors of stars, i.e., the structures within which individual protostellar collapse is initiated.

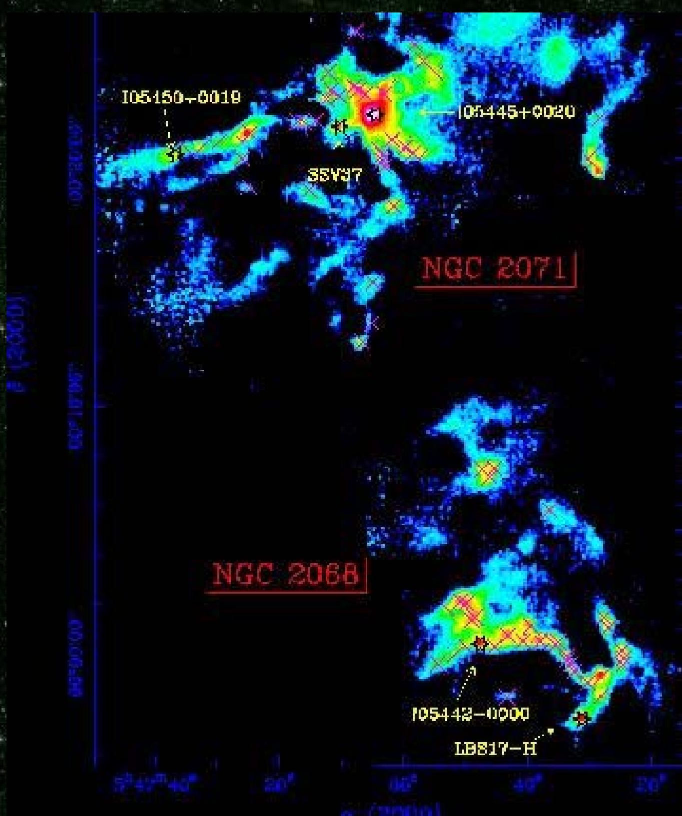


*Figure 1: Dust continuum mosaic of the NGC 2068 and NGC 2071 protoclusters at 850um. Starless condensations are denoted by crosses and young embedded stars by star markers.*

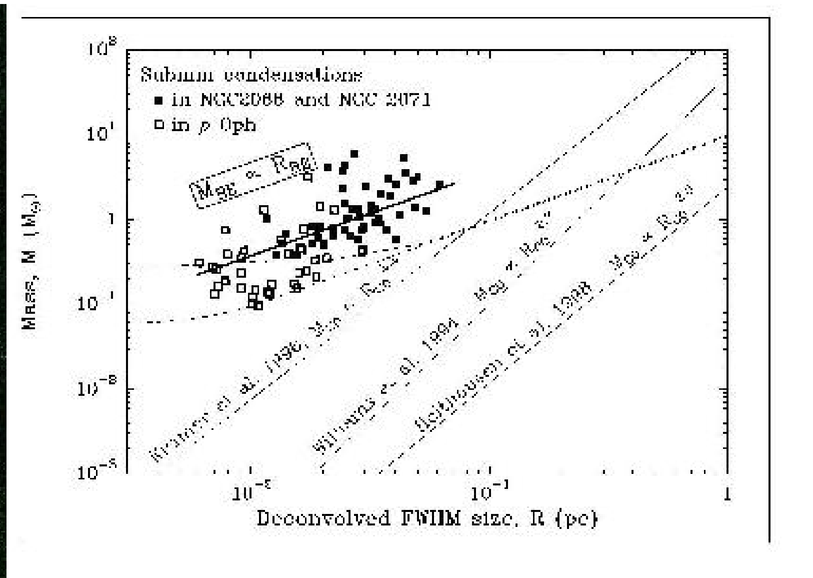


*Figure 2: Mass-size relation of the starless submm condensations identified by Motte et al. (1998) and Motte et al. (2001) in the rho Oph and NGC 2068/2071 protoclusters (open and filled squares, respectively). The thick solid line is the mass-size relation expected for critical Bonnor-Ebert spheres (T = 15K and $P_s \sim 10^5$-$10^7$ $k_B$ $cm^{-3}$ K). The two dashed curves show the 5sigma detection threshold as a function of size in the two protoclusters.*

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# A Single Distance Sample of Molecular Outflows from High-Mass Young Stellar Objects"

**Naomi A. Ridge** (*FCRAO*) & **Toby J. T. Moore** (*Liverpool*)

We have mapped eleven molecular outflows associated with intermediate to high-mass young stellar objects (YSOs) in order to establish whether the correlations between outflow parameters and source bolometric luminosity hold in the high-mass regime. It is important to consider the effects of Malmquist-type biases when looking at high-mass YSOs, as they are generally much more distant than their low mass counterparts. We therefore chose only objects located at ~2kpc. We find that the relations show much more scatter than is seen in similar studies of low-mass YSOs. We also find that the mass-spectrum is significantly steeper in high-mass outflows, indicating a larger mass-fraction at lower velocities, a low collimation factor (~1-2) and no Hubble-like relationship.

Ridge, Naomi A., Moore, Toby J. T. 2001, A&A, accepted.

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*Gerald Moriarty-Schieven*

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# SCUBA sheds new light on the size of Kuiper Belt objects

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**University of Hawaii**

Kuiper Belt Objects (KBOs) are a population of planetary bodies beyond the orbit of Neptune. About 400 of these transneptunian objects are known as of today since the discovery of the first of them in 1992. It is suspected that the Kuiper belt hosts tens of thousands of 100 km size objects and billions of 1 km size. These bodies might be primitive remnants from the early accretion phase of the solar system. They are also believed to be the source of short period comets. Last, many share dynamical properties with Pluto and have for this reason been christened plutinos. These have played a major role in the recent debate on the nature and significance of the ``planet'' Pluto. Hence, the study of transneptunian objects is a current hot topic of planetary science.

The crucial parameter that needs to be determined when studying a planetary body is its size. It is usually obtained by measuring the amount of sunlight reflected by the body. Unfortunately, this quantity is not only proportional to the square of the size, but also to the albedo of the body. Until now, the sizes of KBOs has been estimated by assuming the same albedo as cometary nuclei, which reflect 4% of the light they receive.

A method to determine simultaneously the size and the albedo of a body is to observe at the same time in the optical (to measure the reflected light) and in the infrared (to measure the thermal emission). This method has been applied to many asteroids belt, by observing the thermal emission in the atmospheric windows at 10 and 20 microns. These measurements were successful because asteroids are close to the sun and therefore hot enough to radiate in the mid-infrared. KBOs are much farther and colder : with a temperature near 45 K, the Planck maximum at 70 microns is inaccessible from the ground infrared windows. But these cold objects are within the reach of the most sensitive instruments in the submillimeter windows.

Using the Submillimeter Common User Bolometer Array (SCUBA) on the James Clerk Maxwell Telescope, we have observed the (at the time) brightest KBO 20000 Varuna on the nights of December 30 and 31, 2000 [1]. The observations were done using SCUBA photometric mode, and lead to the detection of the transneptunian body with a flux of 2.81 +/-0.85 mJy at 850 microns. At the same time, we obtained R band images of our target using the University of Hawaii 2.2m telescope. Figure 1 shows the displacement of 20000 Varuna during our observations : by observing on two different nights, we minimized the possibility of detecting a background galactic or extragalactic object. Moreover, we carefully checked that our detection could not be caused by cirrus fluctuation at this low galactic latitude.

Combining our submillimeter and optical fluxes allowed us to determine an albedo of $7^{+3}_{-2}$%, almost twice as large as the cometary nuclei one that was assumed for these objects previously. Our diameter determination is $900^{+125}_{-145}$km, making of Varuna at the third largest transneptunian object after Pluto (2400 km) and Charon (1200 km). We note that this values are relatively insensitive to the parameters of the model we had to assume, essentialy the emissivity of Varuna. Recently, a potentially larger KBO, 2001 KX76 has been discovered, but no direct measurements of its albedo or size have yet been reported.

More information on transneptunian objects and Varuna can be found on Dave Jewitt page at http://www.ifa.hawaii.edu/faculty/jewitt/kb.html.

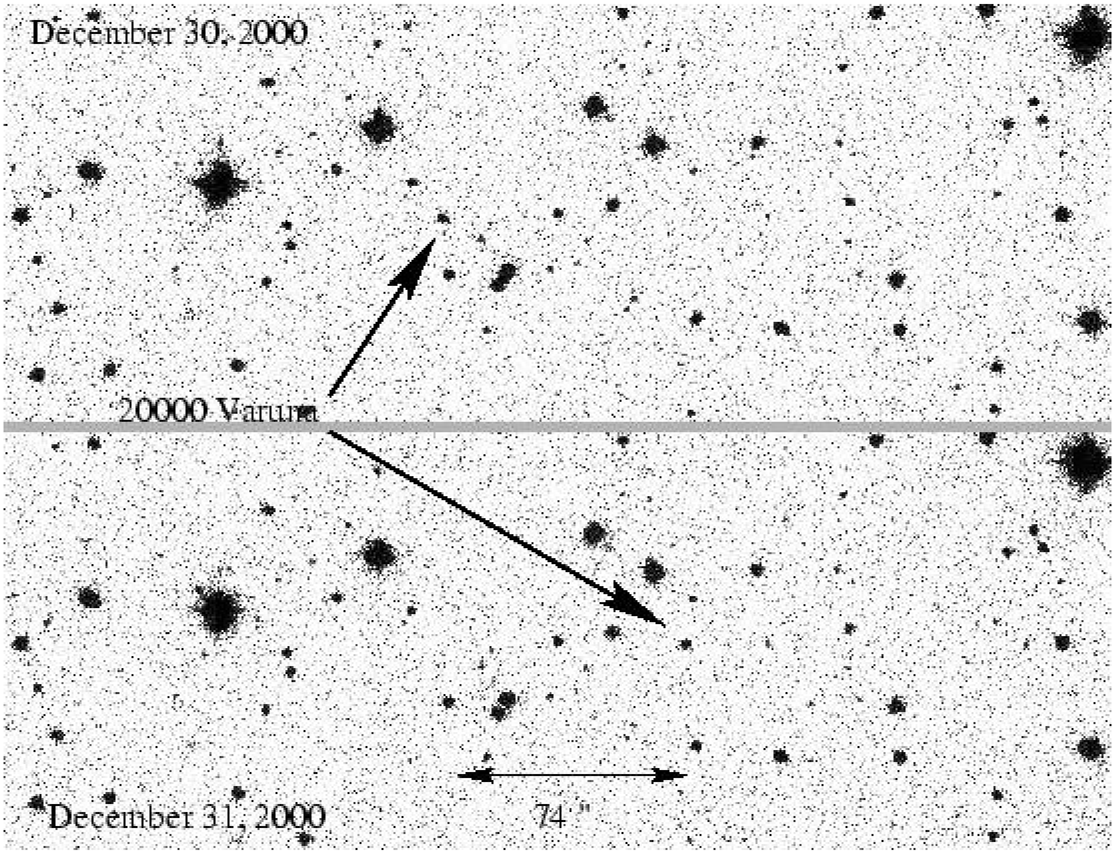


*FIGURE 1: R band images of 20000 Varuna taken at the 2.2m telescope of the University of Hawaii at the same time that SCUBA photometry was obtained.*

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# First Magnetic Field Measurements in Bok Globules

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## Abstract

In order to study the influence and structure of the magnetic field in the early phases of low-mass star formation, we obtained spatially resolved polarization maps of three Bok globules as part of a larger programme at a wavelength of 850 micron, using the Submillimeter Common-User Bolometer Array (SCUBA) at the James Clerk Maxwell Telescope (JCMT). We observed the following sources: CB 26 - a globule with a nearly dispersed dense core containing a source with a circumstellar disk, CB 54 - a deeply embedded young stellar cluster, and DC 253-1.6 (CG 30) - a protostellar double core.

## Introduction

Magnetic fields are an important factor in the star formation process (see, e.g., Greaves et al. 1999, McKee 1999, Mouschovias & Ciolek 1999, Shu et al. 1999). They can influence the contraction timescale, the gas-dust coupling, and the shape of cloud fragments. In the dusty envelopes around young stellar objects, polarization due to dichroic extinction and thermal emission by spinning dust grains is the most important signature of magnetic fields (see, e.g., Weintraub et al. 2000, Clemens & Kraemer 1999, Greaves et al. 1994). The dust grains become partially aligned with the magnetic field, generally with their long axes perpendicular to the field (see, e.g., Lazarian et al. 1997, Draine & Weingartner 1997). Thus, the thermal emission from grains at far infrared and millimeter wavelengths is partially linearly polarized, with a polarization direction perpendicular to the magnetic field as projected onto the plane of sky.

Due to their relatively isolated location, Bok globules are well suited to study the direct interplay between protostellar collapse, fragmentation, and magnetic fields since they are less affected by strong turbulence and other nearby star-forming events. The submillimeter continuum maps trace mainly the dense cores which often consist of central condensations unresolved in single-dish observations and their envelopes. The central condensation can just represent the central dense and warm part of the protostellar core, or an embedded unresolved circumstellar disk. The observations are not sensitive to the low-density material along the path length between the observer and the Bok globule. Thus, one should be able to test the geometrical predictions of theoretical models for star-forming clouds.

## Magnetic field strengths

The polarization maps of the Bok globules CB 26, CB 54, and DC 253-1.6 at 850 micron are shown in Figs.

1, 2, and 3. The mean percentage polarization degrees for CB 26, CB 54, and DC 253-1.6 are 7.3%, 5.1%, and 5.0%.

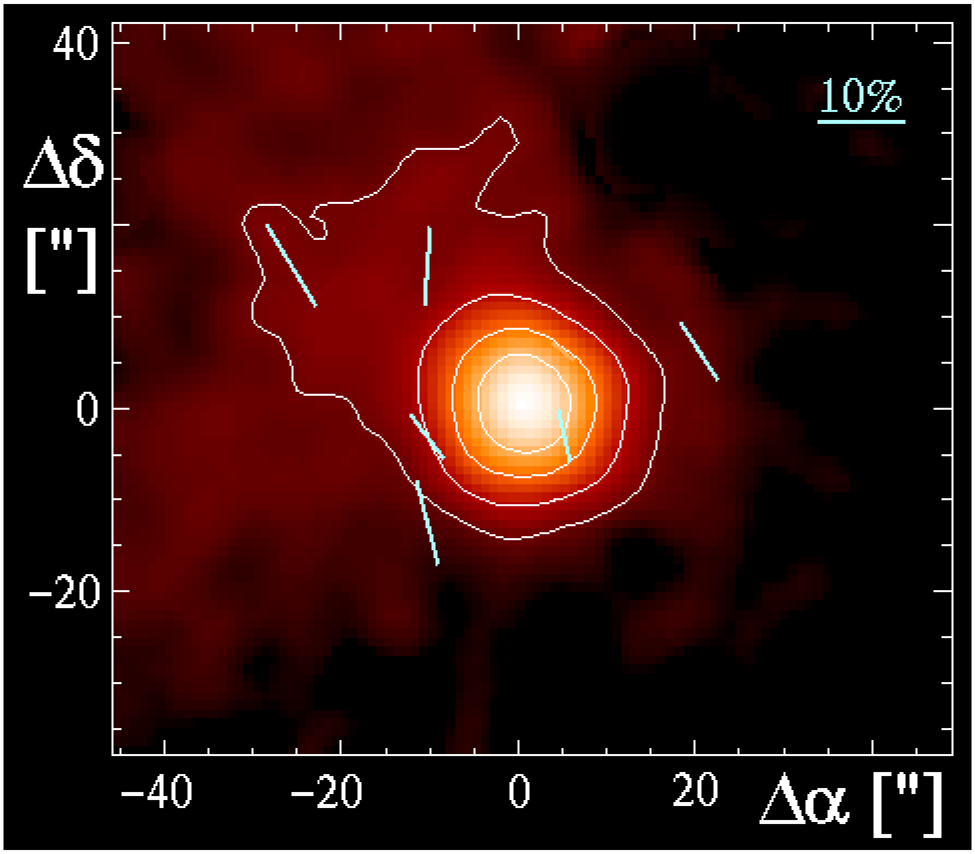
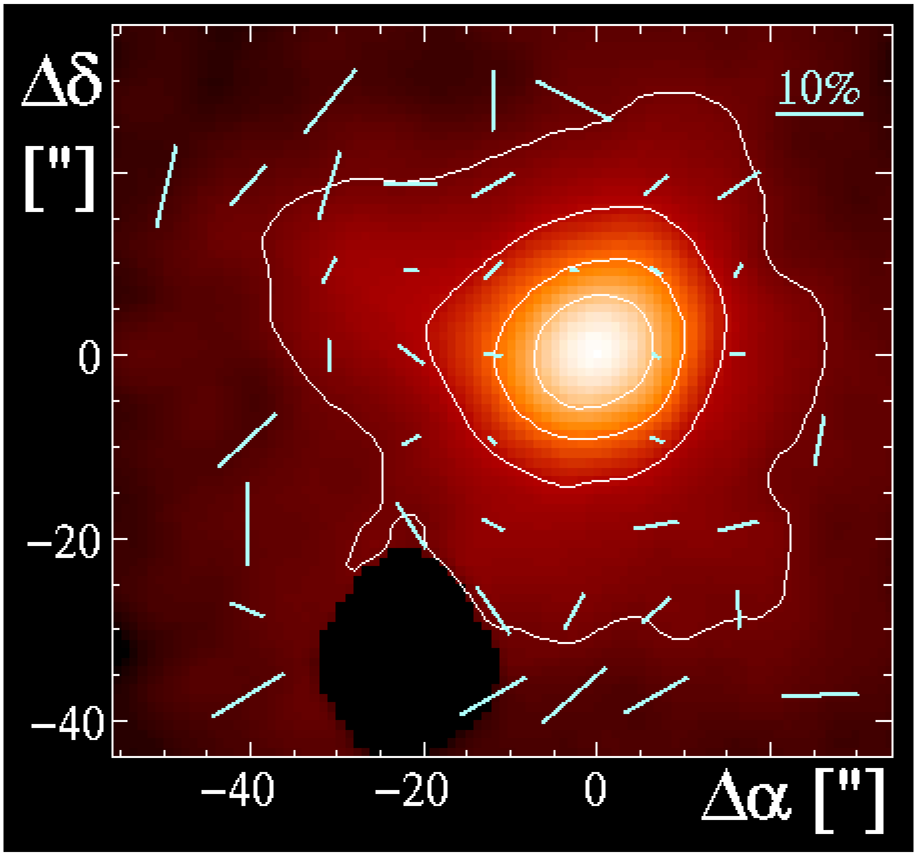
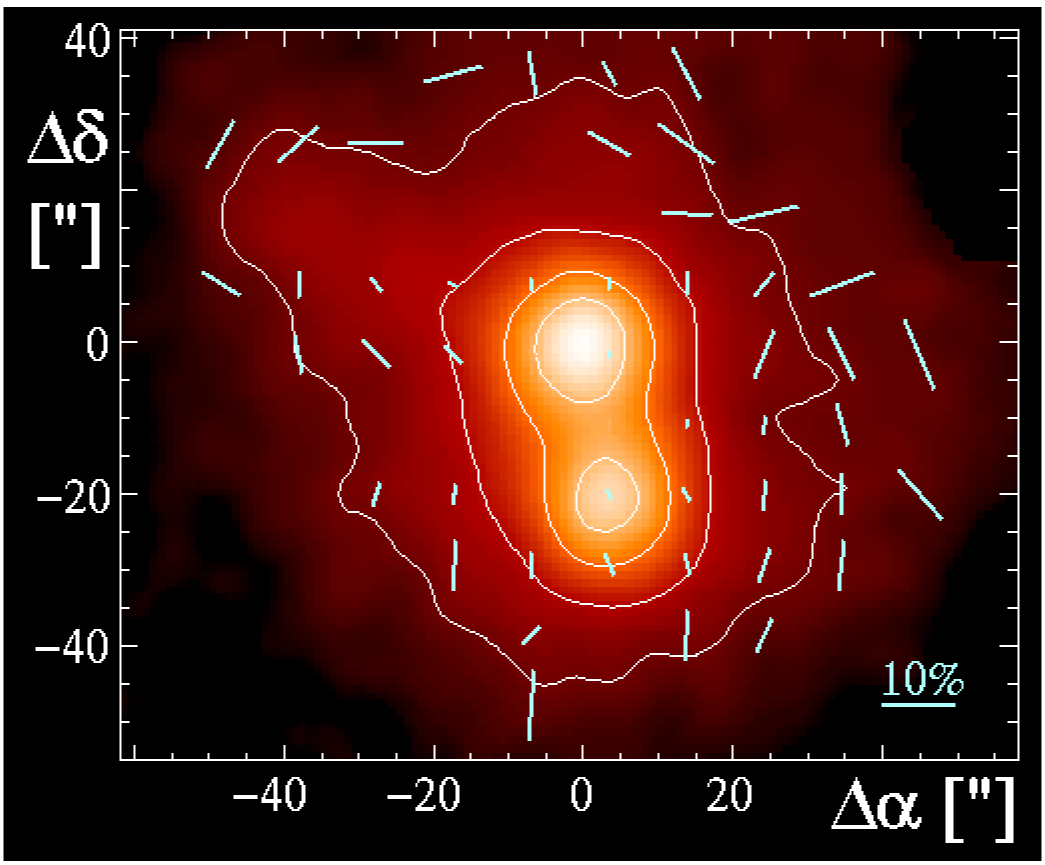



Fig.1 SCUBA 850 micron map of **CB 26** with polarization vectors superimposed.
The length of the vectors stands for the polarization degree and the direction gives the position angle. The data are binned over 9 arcsec. Only vectors in which the 850 micron flux exceeds 5 times the standard deviation and the polarization degree $P > 3\sigma(P)$ are shown.
The contour lines mark the levels of 10%, 25%, 50%, and 75% of the maximum intensity.



<u>Fig. 2</u>  SCUBA 850 micron map of **CB 54** with polarization vectors superimposed.
See text of Fig. 1 for a detailed figure caption.



<u>Fig. 3</u>  SCUBA 850 micron map of **DC 253-1.6** with polarization vectors superimposed.

See text of Fig. 1 for a detailed figure caption.

Following Chandrasekhar & Fermi (1953), the magnetic field strength B [Gauss] can be derived from the gas density ( $\rho$ [g/cm³]), the rms turbulence velocity (v [cm/s]) and the standard deviation to the mean orientation angle of the polarization vectors ($\sigma$ [rad]) as follows: B = sqrt( 4 * $\pi$ * $\rho$ / 3 ) * v / $\sigma$ (see Henning et al. 2001 for a detailed discussion). The resulting magnetic fields are listed in Tab. 1.

| | |
|---|---|
| CB 26 | 74 x 10^-6 Gauss |
| CB 54 | 60 x 10^-6 Gauss |
| DC 253-1.6 | 16 x 10^-6 Gauss |

Tab. 1  Magnetic field strengths

The magnetic field strengths we derived are comparable to those found in molecular clouds (see, e.g., Bhatt & Jain 1992), pre-protostellar cores (Levin et al. 2001), and other star-forming regions (see, e.g., Davis et al. 2000, Glenn et al. 1999, Itoh et al. 1999, Minchin & Murray 1994, Chrysostomou et al. 1994, Crutcher 1999).

## Further Results and Conclusions

For the first time, we obtained spatially resolved submillimetre polarization maps of dense envelopes around the very high-density protostellar condensations in Bok globules. We observed the three objects CB 26, CB 54, and DC 253-1.6 and obtained polarization maps at 850 micron. Despite the fact that these Bok globules harbour a different number of embedded sources (CB 26: single source, DC 253-1.6: double core, CB 54: young stellar cluster and unresolved massive core) and show qualitatively different polarization patterns (CB 26, DC 253-1.6: aligned polarization vectors; CB 54: polarization vectors not aligned), we found the following similarities:

- The polarization degrees amount to several percent.
- In the case of CB 54 and DC 253-1.6, where we have a sufficient number of polarization vectors, the polarization degree decreases towards the globule cores. The functional dependence of this behavior is very similar. This suggests that the optical properties of the grains do not play a key role for the observed polarization decrease, but merely the coupling of the magnetic field to the grains.

The magnetic field strengths we derived from the polarization patterns are well above those of the interstellar medium (see, e.g., Myers et al. 1995). They are similar to those found in molecular cloud cores and protostellar envelopes.

In the particular case of DC 253-1.6, we found for the first time that this source harbours a double core with a projected distance of about 4000 AU. The fact that the projected orientation of this possible binary system is oriented nearly perpendicular to the magnetic field direction projected onto the plane of the sky supports the hypothesis that the fragmentation process of a collapsing molecular core occurs perpendicular to the magnetic field lines.

A preprint of the article (Henning et al. 2001)summarizing the results is available here.

## Acknowledgements

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**Distribution:**

Information about new issues of the JCMT Newsletter is circulated to the community via the electronic distribution list held at the JAC, and also via the Canadian listserver. Anybody wishing to be placed on either of mailing lists should signup by clicking on the appropriate link in the previous sentence.

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**On-line Documentation:**

All up-to-date information on the JCMT and instrumentation is maintained through links from the JCMT homepage at URL:

**http://www.jach.hawaii.edu/JACpublic/JCMT/home.html**

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# NEXT ISSUE DEADLINE

The deadline for submission of science and/or technical articles for the next issue of this Newsletter is **25 February 2002**. *Please consider submitting a short article/figure of your latest result from the JCMT!* All communications regarding this Newsletter should be sent via email to Gerald Moriarty-Schieven (**g.moriarty-schieven@jach.hawaii.edu**).

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